APAT
Agency for the protection of the environment and for technical services

Seed propagation of mediterranean trees and shrubs

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Contents

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Preface

Giorgio Cesari - APAT Director General

The Italian agency for the environment protection (ANPA) has prepared and published the handbook 'Propagation of Mediterranean trees and shrubs by seed' as a contribution to the Italian Committee to Combat Desertification (United Nations Convention to Combat Desertification). It has been printed in Italian in 2001 but afterwards the Agency for the protection of the environmental and for technical services (APAT) decided to translate the essential chapters into English for a wider circulation. This reduced version of the handbook is devoted to everyone who works with propagation of Mediterranean trees and shrubs as it is a compilation of propagation data of 120 Mediterranean plants.
The Mediterranean Ecosystem is undergoing a tropicalisation trend. In the last forty years there has been an increase of 20% in carbon dioxide in the atmosphere and in the last twenty years an increase of temperature has been recorded so that 'greenhouse effect' and 'desertification effect' could be considered as aspects of the same problem. Similarly there is enough evidence with respect to the high number of linkages between desertification, climate change and biodiversity. Nearly 27% of the Italian territory, mainly located in areas with Mediterranean climate and vegetation, is threatened by processes of degradation, erosion or desertification.
Deforestation, especially if followed by overgrazing with soil compactation, can be considered as the principal anthropic cause of groundwater loss in Mediterranean areas. Mediterranean woodlands, especially in arid areas, have diminished considerably and in many cases are degraded with large denuded surfaces characterised by thin soils alternating with outcropping rock. This means that the floristic and structural diversity of the natural vegetation, as well as the faunistic species richness and abundance, is constantly been reduced. Unfortunately, the vulnerability of Mediterranean ecosystems allow a higher negative impact from factors that lead to any form of degradation.
In light of the above, the regeneration and management of woodlands in the Mediterranean needs particular attention: the role of plant cover is essential for mitigating desertification processes because vegetation and connectivity of the 'green' strongly condition the quality and evolution of soil, what is to say the quality and evolution of life.
Mediterranean flora is well described from a botanical point of view. Abundant information is available for what concerns botanical and ecological characteristics, distribution and occurrence, value and use of many species but little is known about their natural and artificial regeneration. The absence of this information is particularly serious because it represents a lack of knowledge within a multipurpose approach to forestation, restoration and reclamation and may explain the reason why plantings are often limited to a narrow number of species which are easy to grow in the nursery. This practice greatly reduces levels of biodiversity and it is even more worrisome with regards to shrubs and minor hardwood which are the greater part (60 to 70%) of the Mediterranean woody flora.
However, many national nursery strategies are focusing on the propagation of a large number of neglected Mediterranean native species and, fortunately, recent research results are having positive effects. Learning how to propagate these 'new' plants properly, including those deserving a wider use as drought-tolerant ornamentals, can be a formidable challenge as well as a powerful tool to combat desertification and enhance biodiversity.

Introduction

B. Piotto

The objective of this manual is to present to administrators, nurserymen and professionals operating in the field of Mediterranean forest management information on the seed biology of Mediterranean trees and shrubs as well as on the available techniques to improve germination and nursery growing. This work has been written also for students, to whom basic scientific tools for further research are provided, and, in general, is dedicated to people who deal with seeds of trees and shrubs. Twenty six authors, mostly Italian but also Australian, English, Polish and Spanish, have contributed to synthesise and amalgamate the available information, which, in part, is the result of their own work as researchers, technicians or nurserymen. Gathering and processing data presented here was not easy because published information on how to propagate Mediterranean species is limited and nursery workers, important sources of knowledge, just do not have the time to document what they know.

More than one hundred trees and shrubs strongly characterising Mediterranean areas are examined, even if, as in a few cases, they are not natives. Those species for which information about propagation was lacking were not considered: the list, therefore, is not exhaustive and someone could be disappointed not to find a plant of particular interest. On the other hand, the text contains a number of species that are not strictly Mediterranean but normally occurring in peculiar Mediterranean micro-environments, e.g. those plants belonging to other climatic bands that for reasons linked to soil conditions and water availability may also grow in Mediterranean regions. Finally, a number of important plants like caper and licorice have been included even if not classifiable as either trees or shrubs.

Plants have been subdivided in *Gymnospermae,* in botanical terms species without true flowers in the division *Pinophyta* of the plant kingdom, and *Angiospermae,* trees with true flowers in the division *Magnoliophyta*. Within these two groups, trees and shrubs are listed alphabetically by genus. Common names are stated as well.

Information is presented as a series of fact sheets which contain the available information on collecting, storage, required pre-treatments to remove dormancy, sowing and practices to be carried out during the first growing stages. The average germination percentage and the number of seeds per kg is also provided where available. Due to the marked variability of seed size and weight, for the parameter 'number of seeds per kg' a range is indicated and within it, when available, the most frequent values for each species are considered between brackets. All measurements are given in metric units.

In nursery practice, the term *seed* refers to any material used for sowing, irrespective of the correct botanical definition, and in this sense it has been used in the text. For example, with regard to the ash tree, *seed* refers to the samara, which actually is not a seed but a winged indehiscent fruit.

As they are still widespread, risky pre-treatments (immersion in hot water or soaking in acids) have sometimes been described for scarifying legume seedcoats. However recent regulations make it difficult to use corrosive substances.

A glossary of technical terms has been included to help in the comprehension of the text.

The *Index Kewensis* is the reference for taxonomy.

1. Why propagate trees and shrubs of the Mediterranean flora from seed

B. Piotto, A. Di Noi

Propagation from seeds ensures that genetic diversity is maintained by allowing genetic recombination to occur through sexual reproduction. The genetic diversity makes possible the survival and the natural evolution of species in continually changing environmental conditions. The rearrangement of genes leads to the production of individuals that are different from their parents and are, therefore, unique and unrepeatable. On the contrary, reproduction without the intervention of sexuality (cloning) means that populations are formed with an identical genetic heritage and therefore it is difficult for them to meet the challenges arising from diseases, insect attacks, climatic changes, etc.
The existence of a marked genetic variability proves especially important in the case of plantations destinated to landscaping, shading, ecological restoration and screening scopes because these are often poorly tended after they have been planted out.
In Italy, the degradation of the soil occurs most seriously in the southern Mediterranean areas, owing to their specific climatic and geomorphological features which, together with incorrect use of the land, results in a high general vulnerability. Within this context, the quality of the soil is very much influenced by the vegetation it supports; therefore plantations for environmental reclamation, using local flora and ecotypes, can ameliorate the problem. For this reason, the Italian National Programme for combating Drought and Desertification, passed on December 21st 1999, envisages sustainable management as well as the development of nursery techniques for the propagation of Mediterranean species as measures to be taken to protect the soil. These protective measures should mitigate the negative effects that global climate changes (especially higher temperatures) may have on the growth and productivity of the Mediterranean forests.
Curiously enough, the Mediterranean flora has been well described from the botanical point of view, but information about seed propagation is quite scarce, while actually, this is fundamental for the production of diversified nursery material destined for environmental reclamation.
To sum up: propagation from seed and the necessary knowledge for accomplishing such a programme can contribute to both protection of biodiversity and also to attenuation of processes of desertification.

2. Trees and shrubs within the Mediterranean environment: subdivision according to morphological characteristics and to temperature zones

B. Piotto, A. Di Noi

The species of trees and shrubs in the Mediterranean environment can be grouped together. According to Bernetti (1995), if such a subdivision is performed on the basis of the morphological features characterising such species and on the basis of their distribution in the geomorphological areas comprising this environment, six main groups can be identified: (1) sclerophyllous broadleaves; (2) the large conifers; (3) the large heathers (*Erica* spp.); (4) shrubs and pioneering bushes; (5) deciduous trees found in woods and sclerophyllous scrubs; (6) species living in salty soil, in dry river-beds and on sand-dunes. On the other hand, following the conventional subdivision by temperature bands throughout the Mediterranean area, we may consider three basic groups of species, each of which represents a temperature area: (1) thermo-Mediterranean zone, (2) meso-Mediterranean zone and (3) supra-Mediterranean zone.

2.1. Subdivision according to morphological characteristics

If we examine the morphological features and the areas of distribution of the main species of trees and shrubs, we may identify the following as being among the most typical in the Mediterranean scrub: the sclerophyllous broadleaves. In this group, the most characteristic evergreens are undoubtedly the oaks, such as *Quercus ilex, Q. suber, Q. coccifera* and *Q. calliprinos,* even though almost a dozen shrubs and trees are included in the same group, such as *Laurus nobilis, Ceratonia siliqua, Pistacia lentiscus, Rhamnus alaternus, Myrtus communis, Arbustus unedo, Olea europaea, Phillyrea angustifolia* and *P. latifolia, Nerium oleander* and *Viburnum tinus* (Bernetti, 1995).
The most widespread Mediterranean forests are undoubtedly those comprising the large conifers, partly because of the reforestation performed recently; these conifers include *Pinus pinea, P. halepensis, P. pinaster, Cupressus sempervirens, Juniperus oxycedrus, J. oxycedrus macrocarpa,* and *J. phoenicea.* The species belonging to this group form the so-called secondary forests, i.e., those forests originating from reforestation programmes as well as those resulting from natural pioneering processes in areas with a climate that discourages competition or that have been subjected to repeated forest fires (as in the case of forests of Aleppo pine, *P. halepensis,* and maritime pine, *P. pinaster*).
A third group of typical Mediterranean species comprises the large heathers (*Erica* spp.), especially *Erica arborea* and *E. scoparia* and a number of other fire-resistant plants.
A group of species may also be identified which are the pioneering shrubs and bushes, among which we may mention all those *Leguminosae* that are commonly called 'broom', such as *Calicotome* spp., *Spartium junceum, Genista* spp., *Ulex europaeus, Teline monspessulana;* pioneering fire-resistant *Cistus,* such as *Cistus monspeliensis, C. incanus* and *C. salvifolius;* aromatic shrubs typical of the Mediterranean, such as *Rosmarinus officinalis, Thymus capitatus, Lavandula* spp., *Helichrysum* spp., and also species with particular features, such as *Chamaerops humilis* and *Euphorbia dendroides.*
On the other hand, if we consider the particular environment colonised or, at least, preferred by the plants, we can identify subgroups comprising all those species that generally live on salty soils, such as *Tamarix gallica* and *T. africana,* in dry river-beds, such as *Nerium oleander* and *Vitex agnus-castus* and in sand-dunes and rocks such as *Juniperus* spp.
Finally, we can place within one large group all those deciduous plants that are often to be found in woods and sclerophyllous scrub, such as *Pistacia terebinthus, Anagyris foetida* and also *Acer monspessulanum* and *Cercis siliquastrum* (Bernetti, 1995).

2.2. Subdivision according to temperature zones

The species belonging to Mediterranean flora are sometimes subdivided conventionally and schematically on the basis of their distribution in the various temperature zones that characterise the Mediterranean environment. To make this subdivision we must first of all identify the main temperature zones characterising this environment. The tree and shrub species can then be identified that have adapted themselves to the environmental conditions characterising those particular zones.
Within the Mediterranean environment three zones can be identified on the basis of climatic conditions, particularly the temperature. They are usually described as thermo-Mediterranean zone, meso-Mediterranean zone and supra-Mediterranean zone (Bernetti, 1995).
The thermo-Mediterranean zone refers to the warmest region of the Mediterranean basin (in Southern Italy it covers a band from sea level to 200 metres a.s.l *circa*). In this zone the climax of the scrub-forest is found, roughly speaking, with carob trees or wild olive and lentisk pistache.
The meso-Mediterranean zone characterises the whole geographical area of the aforesaid region facing the Mediterranean, occurring 200-300 metres above sea level; it also covers the Tyrrhenian coastal areas. A *climax* vegetation of the holly oak (*Quercus ilex*) forests is found prevalently in this temperature zone.
Finally, the supra-Mediterranean zone corresponds to that part of Southern Italy which, in Sicily and especially in Sardinia, is characterised by widespread growth of deciduous broadleaved trees. Owing to the particularly favourable temperature, however, it is not unusual to find *Q. ilex* and other evergreens growing even in those areas included between 400 and 600 metres above sea level.

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3. Fact sheets on the propagation of Mediterranean trees and shrubs from seed

Beti Piotto, Giorgio Bartolini, Filippo Bussotti, Antonio Asensio Calderón García, Innocenza Chessa, Cosimo Ciccarese, Lorenzo Ciccarese, Roberto Crosti, Francis John Cullum, Anna Di Noi, Patricio García-Fayos, Maurizio Lambardi, Marcello Lisci, Stefano Lucci, Susanna Melini, José Carlos Muñoz Reinoso, Stefania Murranca, Giovanni Nieddu, Ettore Pacini, Giuseppe Pagni, Maurizio Patumi, Félix Pérez García, Claudio Piccini, Marco Rossetto, Giuseppe Tranne, Todeusz Tylkowski

The propagation of a number of species that are not strictly Mediterranean, but normally occurring in peculiar Mediterranean micro-environments, is described as well. Usually they are plants belonging to other climatic conditions that for reasons linked to soil characteristics and water availability may also vegetate in Mediterranean regions.

3.1. *Gymnospermae*

3.1.1. Cupressus sempervirens L. (Italian cypress) - *(Cupressaceae)*

Average germination: 20-40%
Number of seeds per kg: 91,000-200,000 (125,000-150,000)
C. sempervirens var. *horizontalis* 145,000
C. sempervirens var. *fastigiata* 180,000
Collection must take place only in good seed crop years. The cones are gathered between the end of summer and the beginning of autumn, when the colour changes from shiny or greyish brown to dark brown. Collection should not include the oldest fruits, which can remain on the tree for as long as twenty years. After collection the cones must be placed in wide-meshed sacks and kept in well-ventilated facilities; plastic bags and airtight containers must be avoided at this stage. The fruits will open when dried in the sun or in drying-rooms at a temperature of +35°C, which can be slightly increased when the moisture content gets close to 10%. The seeds are separated by shaking in a sieve.
If the seeds are kept in airtight containers at +3°C and 5-6% moisture content, they will retain viability for a long time (7-20 years).
The comparatively low germination of the seeds is usually due to the species' poor reproductive efficiency (lack of pollination) or to frequent damage by insects.
The seeds are usually sown in Spring in a seedbed, possibly with seeds subjected to 3-4 weeks cold stratification before sowing. If cold stratification is not carried out, it is good practice to soak the seeds for 2 or 3 days before sowing. When the seedlings have reached the required size, they are transplanted in containers or in nursery beds the open air. In some cases transplanting is not carried out; the seeds are stratified and pre-germinated and afterward sown directly in containers.
During the early stages of development the seedlings are shaded by nets; they are very sensitive to damping-off.
Vegetative propagation can be performed by either cuttings or grafting.

3.1.2. Juniperus spp. (juniper, cedar) - *(Cupressaceae)*

The genus *Juniperus* often displays features typical of the species that live in arid areas: squamiform leaves with 'hidden' stomata and seed dispersal performed by birds (rare in other conifers).
Junipers perform an important ecological task in the Mediterranean regions; they are often the only ones that survive under conditions of extreme drought.
They are dioecious plants: the seeds are produced only on female trees. The pollen produced by the males is carried by the wind to micropilar drops located on the top of the ovules; these are then reabsorbed and the pollen reaches the female gamete. Once the pollen tube has emerged, pollination takes place. The juniper cones contain from 4 to 10 seeds. The cones are produced after a season of growth, although there are some species that need two seasons.

At the end of summer, birds and small mammals feed on the ripe cones and the seeds, which pass through the digestive tract and are attacked by the gastric acids and thus chemically scarified. The seeds, thus 'treated', are then eliminated within a protective sheath of organic matter. After having survived winter frosts, the seeds germinate the following spring or rest dormant for another year.
Dormancy is necessary to prevent germination and there are a number of factors that can influence its duration (the time fruits were collected, the duration and conditions of storage, etc.). Seeds recently dispersed do not show the same dormancy as unripe seeds or seeds that have been stored for a long time.
Many juniper seeds have a semi-permeable coat that causes an exogenous (chemical) type of dormancy, in addition the seeds can show underdeveloped embryos that requires a certain amount of time to pass before they are ripe for germination. The chemical processes that must take place before germination can occur depend upon a number of factors; among these, the most important are the temperature and the time needed to remove the inhibitors. In fact, pre-treatments such as cold stratification encourage the elimination of inhibitors and produce chemical substances that promote germination.
There is considerable variation in the number of viable seeds present in the cone, and also in the dormancy shown by different seed lots and even within the same seed lot. Before collection, it is advisable to subject cones and seeds to cutting tests to check the fruiting characteristics of the plants from which gathering will be done.
After collection, the best way to remove the pulp from the fruit is by maceration, also because the fruits are believed to contain inhibitors that enter the seed through the testa. In this context, it is sometimes suggested to gather green cones in order to avoid or limit the synthesis of inhibiting substances. Alternatively, the seeds may be subjected to lengthy washing to remove the inhibitors or the cones may be gathered dry (grey), when the inhibitors are considered to have degraded naturally.
The non-viable seeds can be separated by floating.
It is possible to store the seeds for several years by reducing the moisture content to 10-12% and placing them in airtight containers at +3°C.
Some authors suggest mechanical scarification of the seeds or cleaning with aggressive detergents to increase germination.
Sowing takes place in autumn, immediately after collection, in well-mulched nursery beds or in spring, in this case with seeds that have usually been warm stratified for 2-3 months and cold stratified for 3-4 months (bearing in mind the requirements of each single species). Instead of warm stratification, the seed can be immersed in sulphuric acid for 30 minutes, although this chemical treatment is extremely risky and, therefore, subjected to the restrictions imposed by safety standards. For some species (*J. communis, J. virginiana, J. osteosperma, J. monosperma),* cold stratification for 2-8 months may be sufficient. The stratification treatments may be useless if very dehydrated fruits or seeds are used.
In some cases *(J. virginiana)*, seeds are immersed in citric acid (10,000 ppm) for 96 hours before a pre-treatment of warm stratification + cold stratification.
After dormancy has been removed, germination is generally encouraged by alternating temperatures.
Shade is advisable during the first stages of development.
Most junipers are easily propagated by cuttings.

3.1.3. Juniperus communis L. (common juniper) - *(Cupressaceae)*

Average germination: very variable
Number of seeds per kg: 56,000-120,000 (80,000-100,000).
J. communis is a typically dioecious species, although it may occasionally be monoecious. Seeds usually ripen after the plant's second season of growth, although it may happen that some fruits ripen after only one season. Mature strobili ('berries') may be dispersed simply by gravity, by water, or by some mammals and by birds; the latter are considered to be the most important dispersing agents as far as the common juniper is concerned. The seeds within the fruit are not damaged by passing through the intestine of the animals that disperse them; on the contrary, this may even favour germination.

The average germination of *J. communis* is comparatively low, as the high number of either empty or not fully developed seeds can be over 60%.
Germination percentage in this species can vary from a minimum of 7% to a maximum of 75%, according to the provenance and the sowing pre-treatment. For example, seeds of some provenances germinate very well after 12-16 weeks of cold stratification; other seed lots, however, do not germinate until the second spring and must therefore be stratified in the open air for at least 15 months (from the autumn, just after collection, until the second spring). In some cases warm stratification for 6-12 weeks followed by cold stratification for at least 12 weeks is suggested. One successful dormancy-breaking pre-treatment, which is hardly practicable, recommends stratification for 8-12 weeks at alternating temperatures (30°C by day and 20°C by night) daily, followed by cold stratification for 12 weeks.
See *Juniperus* spp.

3.1.4. Juniperus oxycedrus L. subsp. *macrocarpa* (Sibth. and Sm.) Ball (sharp cedar, brown-berried cedar) - *(Cupressaceae)*
Average germination: very variable.
Number of seeds per kg: 11,000.
The strobili are dispersed by a number of animals (foxes, wild boar, etc.), which feed on them and thus considerably increase the germinability. However, in some cases the fauna (rabbits) do not act as a dispersal agent since the seeds are destroyed during the digestive process.
Fully ripe fruits are gathered in autumn, when they turn reddish in colour and feel soft. They contain an average of 2-3 seeds that are extracted by macerating the fruit and by hand brushing under a jet of water, to remove resin and inhibitors.
Sowing takes place in autumn in a seedbed, as soon as possible after collection. In hot southern areas germination may occur after 4-6 weeks. Seedlings may be transplanted into bigger containers or in open nursery beds after 4-5 or 12 months. Transplanting is a critical moment in the growing process and, therefore, it must be performed with the utmost care.
See *Juniperus* spp.

3.1.5. Juniperus phoenicea L. (Phoenician juniper) - *(Cupressaceae)*
Average germination: very variable.
Number of seeds per kg: 32,000-50,000
Number of fruits per kg: 1,300-2,300.
This species' seeds are sensitive to a strong desiccation. They are usually dispersed by birds, mainly thrushes, or by small carnivores such as foxes. The strobili are also eaten by other animals (rabbits or pigs) and by ants.
The ripe fruits, those of a reddish colour, are collected in September-October. The fruits, which contain on average 5 seeds, must be soaked in water for one night. Ones that float must not be used for sowing or for pre-treatment, because they are presumed empty.
Ripe fruits fallen from the plant are collected and subjected to pressure, to free the seeds from the pulp. After this, the seeds and the rest of the pulp are passed through a sieve over which some water is also poured, to facilitate recovery of the seeds. They are then put out to dry in a well-ventilated and shaded place. Once they are dry, before pre-treatment or sowing, the clean seeds can be plunged into water so as to identify the ones that float, since these are usually empty or damaged.
The number of empty seeds is high, and may be as high as 60% of the weight of collected seeds. No completely effective pre-treatments are known that will improve germination but we would suggest cold stratification of naked seed at +3°C or +4°C for 30-90 days. Periods longer than 90 days of cold stratification may sometimes result in premature germination during the pre-treatment itself. In some cases periods longer than 30 days of cold statification can influence germination negatively. Alternatively, the seeds may be placed either in a solution of 95% sulphuric acid for 45 minutes (this chemical treatment is extremely hazardous and, therefore, subjected to the restrictions imposed by safety standards) or in 20% oxygenated water for an hour.
Some nurseries in Sardinia sow the seeds in a seedbed in October (germination may begin after 5-6 weeks), transplanting the seedlings the following March.

After dormancy has been removed, germination may be encouraged by temperatures of about +15°C, while higher temperatures (+20°/+25°C) do not seem to be optimal.
See *Juniperus* spp.

3.1.6. *Pinus* spp. (pines) - *(Pinaceae)*
Seeds of the *Pinus* are typically orthodox, thus they maintain viability for many years if they are stored at low temperatures (from −5°C, but even lower, and up to +5°C), with 5-8% moisture content. The sowing period is typically in spring, with seeds having been cold-stratified, or not, depending on the species. In the hot southern regions sowing in late summer is not infrequent.
The seeds of those species that require cold stratification allow stratification of naked seeds. In this case, they are immersed in water for 24-48 hours and then drained. Then the seeds are placed in plastic bags of no more than 10 kg (for practical reasons) in refrigerators or cold-stores. The bags must not be sealed, to allow gaseous exchange inside. Stratification of the seeds without an substrate permits a considerable saving of space and simplifies manual operations. Cold stratification of naked seeds is carried out at lower temperature (about +3°C) than traditional cold stratification with a substrate (about +5°C). The soaked seeds contained in the bags are stirred periodically to improve aeration. Emanation of an odour of alcohol warns of limited aeration.
Propagation by cuttings and also by grafting is employed for some ornamental varieties.

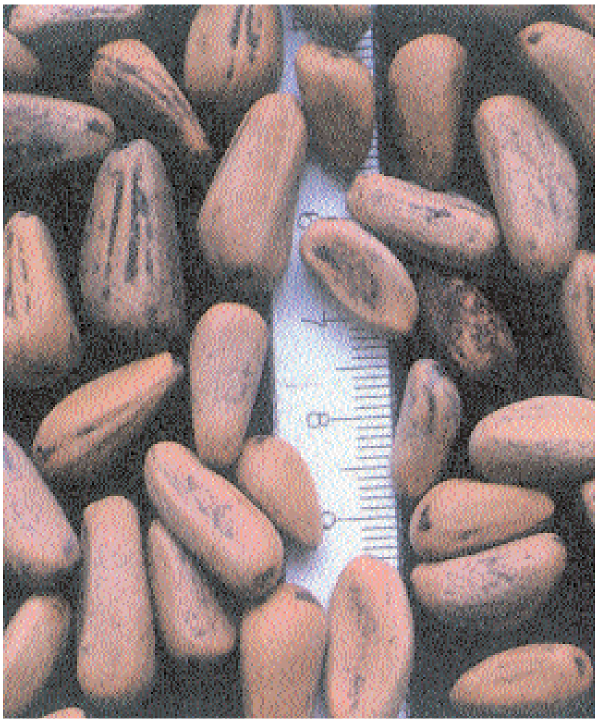

Figure 1. Seeds of *Pinus pinea* (L. Mezzalana)

3.1.7. Pinus brutia Ten. *(=P. halepensis* Miller var. *brutia* (Ten.) Elwes and Henry) (hard pine, erect-cone Aleppo pine) - *(Pinaceae)*
Average germination: 80%
Number of seeds per kg 14,000-30,000 (17,500-19,000).
Seeds with a moisture content of 6-7% can be stored for a long time if they have been placed in airtight containers at +3°C.
Sowing is done in spring, possibly with cold-stratified seeds (4-8 weeks).
Cold stratification proves to be particularly effective for seeds that come from areas characterized by hard winters.

3.1.8. Pinus halepensis Miller (Aleppo pine) - *(Pinaceae)*
Average germination: 80-85%
Number of seeds per kg: 50,000-100,000 (52,000-60,000).
Sowing is performed in spring. In very hot southern regions sowing is sometimes performed in late summer.

3.1.9. *Pinus pinaster* Aiton (maritime pine) - *(Pinaceae)*
Average germination: 70-90%
Number of seeds per kg: 15,000-28,000 (18,000-20,000).
Long-term storage of the seeds is possible by keeping their moisture content at 5-8% and placing them in airtight containers at a temperature varying between +3° and +4°C.
Sowing takes place in spring with seeds that have not been pre-treated or that have been cold-stratified for 4-12 weeks (usually 4); the pre-treatment has a positive effect on the uniformity of emergence, especially when seeds that have been stored for a long time are used. Cold stratification without a substrate (naked seeds) is frequent.

In hot southern areas, late summer sowing is often performed.

3.1.10. Pinus pinea L. (Italian stone pine) - *(Pinaceae)*
Average germination: 80-90%
Number of seeds per kg: 900-2,000 (1,200-1,300).
Seeds can be safely stored for long time at 5-7% moisture content, when kept in airtight containers at +3°C.
Sowing takes place in spring, but in the hot southern areas it may take place in late summer.

3.2. *Angiospermae*

3.2.1. Acer spp. (maple) - *(Aceraceae)*
The seeds often display an endogenous dormancy since the embryo requires a period of after-ripening which occurs in nature during the cold season or, in nursery practice, during cold stratification. The length of this period varies according to the species and, within the species, to the provenance. The seeds that have undergone pre-treatment have to be regularly checked for swelling and they are sown as soon as germination is seen to have commenced in the stratification medium. Maple seeds germinate easily even at low temperatures (between +3° and +5°C).
Sowing can be done with winged or dewinged seeds. However, this latter practice is not very widespread because it can have a negative effect on the quality of the seeds.

3.2.2. Acer campestre L. (field maple, small leaved maple) - *(Aceraceae)*
Average germination: 60-80%
Number of seeds per kg: 8,600-15,000 (12,000)
This species' seeds are considered orthodox as regards their behaviour during storage. They are sown in autumn, without any pre-treatment, or in spring with seeds subjected to 3-8 weeks warm stratification followed by 12-24 weeks cold stratification. Alternatively, seeds cold-stratified only (13 weeks) may be used. Some authors advise only immersing the seeds in water at +40°C (constant) for 3 days before sowing.
Vegetative propagation is possible by means of hardwood or semi-hardwood woody cuttings.

Figure 2. Young seedling of *Acer campestre* (L. Mezzalana)

3.2.3. Acer monspessulanum L. (Montpellier maple) - *(Aceraceae)*
Average germination: 40%
Number of seeds per kg: 15,000-30,000
Autumn sowing, without pre-treatment, or spring sowing with seeds cold-stratified for 8-12 weeks.

3.2.4. Acer opalus Miller *(= A. opulifolium* Chaix*, A. obtusatum* Waldst and Kit, ex Willd*, A. neapolitanum* Ten.) (opalus maple) - *(Aceraceae)*
Average germination: 80%
Number of seeds per kg: 10,000-15,000
Autumn sowing, without any pre-treatment, or spring sowing with seeds subjec-

ted to cold stratification for 4-12 weeks. Stratification medium (sand, peat, etc.) can be used or not (naked stratification). Warm stratification for 4-12 weeks, preceding cold pre-treatment, might improve the effectiveness of the whole treatment. Towards the end of cold- stratification, pregermination within the stratification medium must be monitored because the seeds of these species may also germinate at rather low temperatures.

3.2.5. *Alnus cordata* Loisel (Neapolitan alder) - *(Betulaceae)*
Average germination: 40-60%
Number of seeds per kg: 350,000-550,000 (430,000-500,000)
The quality of the seed is affected by the collection time. If the seeds are gathered too soon they have a low vigour and germination percentage, there is a high number of empty seeds as well.
The seed store well at temperatures between –3°C and +3°C, in airtight containers; the moisture content must be between 5% and 7%.
Seeds are sown by the end of February without any pre-treatment or in spring with cold-stratified seeds for 4-6 weeks (pre-treated with or without stratification medium, 'naked' stratification). At the conclusion of a 'naked' stratification, the seed is put in a dry place so that it can dry superficially and thus be easier to handle during the sowing operations.
Vegetative propagation is possible.

3.2.6. *Alnus glutinosa* (L.) Gaerther (black alder, common alder) - *(Betulaceae)*
Average germination: 30-40%
Number of seeds per kg: 635,000-1,400,000 (800,000-1,000,000)
Germination is strongly enhanced by light, but the seeds can also germinate in the dark, albeit with difficulty. Fresh seeds (just gathered) germinate immediately and have no need of stratification. On the contrary, dry seeds (8-9% moisture content) require pre-treatment to remove their dormancy.
In this species dormancy varies according to the provenance, but it is usually more accentuated than that of *A. cordata.* The germination of dry seeds, stratified for 4-5 months at +4°C, is greater than that of fresh seeds. Seeds that have been dried and then stored in airtight containers at a temperature of between 0° and +4°C may remain viable for up to 2 years.
Vegetative propagation is possible.
See *A. cordata.*

3.2.7. *Amorpha fruticosa* L. (false indigo, indigo bush) - *(Leguminosae)*
Average germination: 60-90%
Number of seeds per kg: 60,000-200,000.
Sowing takes place in autumn, without any pre-treatment, or in spring with seeds that have undergone cold stratification during the winter. Mechanical or chemical scarification (immersing in sulphuric acid for 5-8 minutes) are said to substitute for cold stratification in spring sowings. Clean seeds or one-seeded (monospermous) pods may be used.
Spring sowing with mechanically scarified seed is preferable to the acid treatment for reasons of safety and effectiveness.
Vegetative propagation by means of semi-hardwood cuttings collected during the summer is easy.
See *Leguminosae.*

3.2.8. *Anthyllis* spp. - *(Leguminosae)*
Average germination:?
Number of seeds per kg:?
Information about the germination of the species belonging to this genus is very scarce. As regards *A. vulneraria,* mechanical scarification is the optimum pre-treatment for germination. Once they have been scarified the seeds germinate well at temperatures between +10°C and +30°C as well as at alternating temperatures (+20°/+30°C).
See *Leguminosae.*

3.2.9. Arbutus unedo L. (strawberry-tree) - *(Ericaceae)*

Average germination: 60-90%

Number of seeds per kg: 330,000-700,000

Among the species of the genus *Arbutus* (about 20 in the Northern Hemisphere), the characteristic ones in the Mediterranean environment are *A. canariensis* Lindl., *A. californica* Sarg., *A. menziesii* Pursh. and *A. unedo* L.; the latter is widespread throughout the Western Mediterranean as far as Greece.

The strawberry-tree berries are fleshy fruits particularly suitable for endozoochoric dispersal. In fact, the berries with a fleshy pulp are eaten especially by birds and mammals, which are responsible for the dispersal of the tiny seeds enclosed within (from 10 to 50 seeds per berry).

Figure 3. Unripe fruits of *Arbutus unedo* (P. Orlandi, APAT)

As regards nursery growing, strawberry-tree berries offer a problem: in fact, they are difficult to store because the fleshy whole fruits are subject to fungal infection and fermentation. Thus, propagation by seed involves processing the seeds, beginning with maceration of the ripe fruits to remove the pulp. The collected berries are soaked in water (three parts of water to one of fruit) for several hours, they are rinsed in a sieve to remove the residue and finally, still in water, they are put into a mortar and delicately mashed with pestle. Then the split berries are soaked in water for another 24 hours to soften pulp further and afterwards rubbed between the fingers to loosen seeds from skin, pulp and other chaff. Then they are put into a household blender, which has been modified by replacing the metal blades with rubber ones, at the lowest possible speed (water is added to make a 3:1 ratio of water to berries). Following this, the seeds are pressed through a set of sieves, starting with the sieve with the largest mesh, with the aid of water jets under pressure. After drying the seeds thus processed, they can be stored for short periods (1-3 months) in jute sacks.

Although it is not always essential, cold stratification of the seeds for 20-60 days produces more complete and simultaneous germination. Sowing in trays or seedbeds may be performed in autumn, without pre-treatment, or spring, with cold-stratified seeds. Whenever seeds germinate at a high density in seedbeds or in containers, the surplus seedlings have to be thinned out. Subsequently the seedlings are carefully transplanted and properly shaded during the hot months. In many cases, the seeds are sown directly into containers to avoid the stress of transplanting.

Considering the small size of the seeds, it is advisable to cover them with a very thin layer of light, porous medium which will also permit the positive effect of light on germination.

Vegetative propagation by cuttings is possible.

3.2.10. Artemisia arborescens L. (artemisia, shrubby wormwood, southernwood) - *(Compositae)*

Average germination:?

Number of seeds per kg:?

This species, characterised by tiny fruits and seeds, flourishes in the hottest parts of the Mediterranean. It has a marked xerophytic character; living on stony coasts and rocky slopes.

Very little information is available about the biology of *A. arborescens* seeds, but no dormancy is presumed for other species of the genus *Artemisia (A. absinthium, A. dracunculus, A. maritina, A. vulgaris).*

The ideal conditions for the germination of the genus *Artemisia* seem to be daily alternating temperatures of +30°C/+20°C (day/night).

3.2.11. Asparagus acutifolius L. (asparagus) - *(Liliaceae)*
Average germination:?
Number of seeds per kg:?
Autumn or spring sowing, in either case after soaking in hot water for 12 hours. Germination may occur after 3-6 weeks in conditions maintained at +25°C. The seedlings are delicate during the first stages of development.
With regard to *A. officinalis,* cold stratification may be performed for 30-60 days and then sowing is carried out in conditions of alternating temperatures (+30/+20°C). Scarifying the seeds may also be useful.

3.2.12. Atriplex spp. (saltbush) - *(Chenopodiaceae)*
The germination percentage may vary between 10 and 90%, according to the species.
The number of seeds per kg varies according to the species between 115,000 and 2,100,000.
The species belonging to this genus usually live on terrains where there is a very high salt content.
Dispersal, often by wind or by animals, may be protracted for a long period (from late autumn until the following spring).
The so-called seeds are actually achenes, sheathed by persisting bracts.
Vacuum machines can be used to collect the fruits or collection may be performed by laying sheets under the shrubs. The attachment of the fruits to the plants is such as to permit collection from early winter up to late spring. In many cases, the collected fruits are crushed mechanically and then exposed to ventilation to reduce the volume and facilitate handling and sowing. The percentage of empty seeds varies according to the species, but can reach very high values, especially if the material comes from wild populations.
The seed generally stores well, even in structures where the temperature cannot be regulated. If brought to a moisture content of 6-8% and kept in jute sacks in cool, dry conditions the seeds will maintain their viability for a long time (3-10 years).
The germination characteristics vary considerably according to the species. Germination is often hindered by woody bracts, which hold the fruit and seeds tightly, leading to problems of indehiscence, impermeability to water and gas and the impossibility of eliminating any inhibiting substances that may exist in the embryo. Thus separating the seed from the fruit is useful even from a physiological point of view. Various species of *Atriplex* concentrate an excess of salts in the flower bracts and these substances may subsequently interfere with the germinative processes. A lengthy washing of the fruits before sowing may, in these cases, be a useful pre-treatment. The seeds of a number of species germinate better at comparatively low but constant temperatures (between +13° and +20°C); this characteristic could permit the seedlings to develop in cool, moist periods (autumn), as a strategy of adaptation to arid or semi-arid conditions. Other species, on the contrary, show a strong interaction between alternating cycles of temperature and conditions of low osmotic potential.
Since the seeds of many varieties show embryonic dormancy, cold stratification for 15-30 days is thought to improve their germination. This is why sowing is performed in late autumn or winter in many cases, taking care not to sow the seed too deeply (no more than 1 cm of soil).
In cool, moist areas the seedlings are very susceptible to fungal infection (damping-off) during their first 15 days of life. Therefore, it is good practice to provide little or no shade. The seedbeds are to be protected from birds and rodents, which are especially fond of the seeds and seedlings.

3.2.13. Atriplex halimus L. (sea orache, Mediterranean saltbush) - *(Chenopodiaceae)*
Average germination: 50-90%
Number of seeds per kg: 650,000-2,000,000
The seed of this species can show both morphological and physiological polymorphism; the latter is often linked to salinity tolerance. The bracts surrounding the seeds are thought to con-

tain substances that inhibit germination and therefore removal of these modified leaves might improve germinability.
A high degree of salinity in the ground also has a negative effect on the germination of this species' seeds.
Pre-treatments based on immersion in hot water, in boiling water for 5 minutes or soaking in tepid (room temperature) water for 48 hours have not proved to be useful for improving the germination of *A. halimus*. However, immersion in tepid water improves the germination of other species of the genus *Atriplex* (*A. canescens, A. lentiformis* and *A. nummularia).*
If it is properly dried, the seed can be stored in a wide range of temperatures (from –22° to +21°C).
Under natural conditions, the allelopathic effects of some species present in pastures, such as *Salsola vermiculata* and *Rhazya stricta,* may inhibit the germination of *A. halimus* seeds.
Sowing in January-February is widespread without any particular pre-treatments.
It propagates easily by vegetative means.
See *Atriplex* spp.

3.2.14. Berberis spp. (barberry) - *(Berberidaceae)*
Sow in mulched seedbeds in autumn, without any pre-treatment of seeds, or spring sowing, using seeds or berries cold-stratified for 6-13 weeks. However, it is preferable to use seeds rather than fruits, because the latter are susceptible to fungal infections.
Vegetative propagation is possible by means of semi-hardwood cuttings.

3.2.15. Berberis vulgaris L. (common barberry, European barberry) - *(Berberidaceae)*
Average germination: 70-90%
Number of seeds per kg: 75,000-90,000
The seeds may be easily stored for several years if they are placed in airtight containers at +1°/+2°C.
It is preferable to sow the seeds as soon as the fruits have ripened, because seeds extracted from over-ripe fruits may give unreliable results. Sow in mulched seedbeds in autumn, without any pre-treatment of seeds, or spring sowing, using seeds or berries cold-stratified for 6-13 weeks. Seeds are preferable to fruits for sowing because the latter are susceptible to fungal infections.

3.2.16. Calycotome spinosa (L.) Link (gorse, spiny calycotome) - *(Leguminosae)*
Average germination: 80-90%
Number of seeds per kg:?
Spring sowing with seeds previously soaked in hot water (+40°C) for 15 minutes. In very hot regions, sowing sometimes takes place at the end of the summer, even without any pre-treatment.
See *Leguminosae.*

3.2.17. Capparis spinosa L. (caper, caper bush) - *(Capparidaceae)*
Average germination: 70-95%
Number of seeds per kg: 80,000-160,000
The ripe berries are collected from July to September (from may in the hottest regions) and are dried. Each plant can produce from 1 to 5 kilos of fruit, according to the seasonal trend. The seeds are extracted, washed and dried for storage. Fully ripened seeds are usually dark brown in colour, while unripe ones are much paler. The seeds are dispersed by ants, lizards and birds.
The seeds have impermeable seedcoats (physical dormancy) that hinder moistu-

Figure 4. Flower of *Capparis spinosa* (P. Orlandi, APAT)

re uptake. If they are mechanically scarified immediately after collection, a moderate level of of germination can be achieved. Some authors theorise that some other type of dormancy may develop following seed dispersal.
Mechanical or chemical scarification (with sulphuric acid for 15-30 minutes) is suggested; following this the seeds are washed with water and soaked for 60-90 minutes in a solution of gibberellins (GA_{4+7}, 100 ppm or GA_3, 400 ppm). When this technique is employed, in which the gibberellins have a secondary synergic effect upon the abrasion to the seedcoats caused by the scarification, germination percentages above 70% have been achieved.
Scarification by immersion in hot water (from +55°C to +85°C) proves to be generally ineffective.
Partial or total removal of the seedcoats performed by hand results in very high percentages of germination; this demonstrates the fundamental role of the seedcoats in the caper's germination. The pre-treatment described above, although not practicable at the nursery level, suggests which path should be followed for improving the germinability of this species' seeds.
After dormancy has been broken, germination is favoured by alternating temperatures, but good results have also been achieved with constant, and comparatively high, temperatures (+25°C) and a 12 hours photoperiod.
With regard to other species of the *Capparidaceae* family, abrasion of seedcoats or clipping off a small portion the seed is suggested, followed by germination in the substrate moistened with a 0.2% solution of potassium nitrate.
When the seedlings are large enough to be handled they can be transplanted into containers. Vegetative propagation is possible.

3.2.18. Carpinus orientalis Miller (oriental hornbeam) - *(Betulaceae)*
Average germination: 80-85%
Number of seeds per kg : 70,000-85,000
After collection of ripe fruits (autumn), they are put to dry in thin layers in fresh, well-aerated facilities. In some cases dewinging is done by hand. Some authors suggest to gather fruits when their wings are still soft and flexible. The seeds, dried until they reach 10% of moisture content, can be stored for about 18 months if placed in sealed containers at +2°/+3°C.
If fresh seeds (collected during the autumn preceding the spring sowing) are going to be used, 3 months cold of stratification are enough to remove dormancy. However, for spring sowings, it is better to sow warm (3-4 weeks) + cold stratified (12-15 weeks) seeds.
After dormancy has been removed, alternating temperatures of 25°C (8 hours with light) and 20°C (16 hours in the dark) seem to stimulate germination but even more marked fluctuations of temperature (25°C/10°C) are suggested.
Vegetative propagation by grafting and cuttings is possible.

3.2.19. Celtis australis L. (European hackberry) - *(Ulmaceae)*
Average germination: 50-90%
Number of seeds per kg: 4,000-10,000 (6,000-7,000)
Dry fruits per kg: 2,000-4,500.
The pulp is usually removed from the fruits by maceration, before sowing or storing. Dry seeds or fruits will store well for several years if they are placed in airtight containers at +4°C and if the moisture content is reduced to levels of less than 10%.
Sowing takes place in autumn, without any pre-treatment of seeds, or in spring, with seeds subjected to cold stratification for 8-12 weeks.
The state of the seeds in the stratification medium ought to be checked often and the treatment interrupted as soon as the commencement of germination is observed.
Vegetative propagation by semi-hardwood cuttings is possible.

3.2.20. Centaurea cineraria L. (dusty miller) - *(Compositae)*
Average germination:?
Number of seeds per kg:?
There are no particular problems with germination, provided that it takes place in a well-drained substrate at a temperature of between +15° and +20°C.

A brief period of cold stratification may improve the rate and uniformity of germination. Light is advised for other species of the genus as an element for optimising germination.
Some species of the genus *Centaurea* are dispersed by ants.
Spring sowing.
Vegetative propagation is possible.

3.2.21. Ceratonia siliqua L. (carob tree) - *(Leguminosae)*
Average germination: 60-95%
Number of seeds per kg: 4,500-6,000
Ceratonia siliqua seeds are brown, with extremely tough and impermeable seedcoats that impede water absorption, thus hindering germination.
The particular hard seedcoats allows the formation of soil seed banks, the dispersal by large mammals that feed on them as well as the survival after fires (that are very frequent in the areas where this species occurs).
There is a certain degree of variability between seeds as far as the toughness of the seedcoats is concerned, both within one seed lot and also between lots from different provenances. Without any pre-treatment, the germination percentage rarely exceeds 10%, which in any case proves the existence of a certain number of seeds with less impermeable seedcoats; however, if simultaneous germination is wanted the integrity of the seedcoats can be attacked by scarification. One of the most used methods is based on soaking the seeds for 12-24 hours in water that is boiling when the seeds are plunged into it. The source of heat must be removed before the seeds are immersed and the whole, formed of ten parts of water to each part of seeds, must be stirred from time to time until the water has cooled. Once they have been removed from the water, the seeds are dried in a well-ventilated areas, not exposed to the sun, and sown as soon as possible. The treatment is not devoid of risks for both the people performing it, especially when large quantities of hot water are being used, and also for the seeds themselves, because the ones with the most vulnerable seedcoats may be damaged and thus subjected to a genetic selection. Two effective variations of the aforesaid treatment consist of immersion for 5 minutes in water at +90°C (5 volumes of water for each volume of seeds) or soaking in water for 24-48 hours at +40°C.

Figure 5. Unripe pods of *Ceratonia siliqua* (L. Ciccarese, APAT)

Alternatively, scarification may be performed with acids or alkalis (chemical scarification) or by the appropriate machines (mechanical scarification). The former method is not advisable, because of the risks that may arise from handling corrosive substances and because the seeds with the thinnest seedcoats may be damaged. However, one chemical treatment that makes it possible to achieve a high degree of germination is advised: it consists of immersing the seeds for 20 minutes in 90% sulphuric acid (5 volumes of acid for each volume of seeds); the seeds are then washed in running water for 48 hours.
There is a vast bibliography relating to scarification performed with acids or boiling water. In practice, however, it is always appropriate to check the validity of the techniques described here, by means of preliminary tests carried out on small samples of seed. Indeed, as already noted, there is a considerable variability in the toughness of the seedcoats, while information relating to the pre-treatments to be employed is often contradictory.
Mechanical scarification, performed with electrically operated scarifiers, is a simple and effective technique, but it is almost unknown in Italy. It can considerably increase the degree and rapidity of germination. This technique employs mechanical equipment comprising a metal cylinder lined inside with sandpaper, and a series of central blades which spin at a high speed, propelling the seeds against the walls and scarifying the seedcoats, only rarely damaging the embryo. The most suitable sandpaper and the optimum duration of scarification has to be

established for each sample; the duration does not usually exceed 60 seconds at a speed of 1200 revolutions per minute. In order to judge the effectiveness of the treatment after the preliminary scarification test, the seeds are soaked in water and after several hours the percentage of imbibed seeds is checked. If imbibition has occurred, it means that the seedcoats have been scarified. Ripe seeds pre-treated by this technique germinate rapidly after having been placed in suitable conditions, but scarified seeds with moisture content not higher than 10% can otherwise be stored (in sealed containers or under vacuum at temperatures varying from -3°C to +3°C) for at least 18 months without the quality of the same being altered in any way.
Scarified seeds germinate well at either constant temperatures of between +10° and +25°C or at alternating temperatures (+15°/+25°C).
To sum up, propagation of the carob tree by seed does not pose any particular problems, except for the necessity to subject the seeds to one of the following treatments: soaking in hot water, soaking in concentrated sulphuric acid (with subsequent washing in water) or mechanical scarification.
For reasons of safety and effectiveness of the pre-treatment, spring sowing is to be preferred, using mechanically scarified seeds. Moreover, for nursery growing, the use of containers that prevent from root coiling is advisable. The species does not easily bear damage to the roots.
Vegetative propagation by cuttings is possible, taking into account several factors that are decisive for successful rooting: the period of collection, the type of cutting (topophysis is important) and the characters of the mother plant (rooting capacity varies according to the genotypes). Micropropagation is also possible.
See *Leguminosae.*

3.2.22. Cercis siliquastrum L. (Judas tree) - *(Leguminosae)*
Average germination: 70-90%
Number of seeds per kg: 30,000-60,000 (40,000-50,000)
Spring sowing with scarified seeds.
Some seed lots require scarification followed by cold stratification for 4-12 weeks, since besides physical dormancy due to the seed seedcoats, some of them prove to have endogenous dormancy. This dual treatment (scarification + cold stratification) is applied to other leguminous plants only in exceptional cases.
Soaking in tepid water for 24 hours followed by cold stratification for 12 weeks is often suggested for seeds that have been stored for a long time.
However, spring sowing of mechanically scarified seed is to be preferred.
Vegetative propagation is possible by grafting; it is difficult to perform by cuttings.
See *Leguminosae.*

3.2.23. Chamaerops humilis L. (Mediterranean palm, dwarf fan palm, hair palm) - *(Palmae)*
Average germination: 80-90%
Number of drupes per kg: 1,630 (fresh: 654)
The fruits are collected in autumn (September-November).
First of all, soak the fruits in water for 24 hours and then let them germinate in a hot bed (between +20° and +25°C). It is preferable to remove the flesh from the drupes before sowing, by means of maceration for 4-6 days, because the fleshy tissues are vehicles for substances that inhibit germination and for pathogenic agents. Moreover, they emit a disagreeable odour.
In some hot areas in the South autumn sowing is practised immediately after the collection, germination commencing the following spring.
Vegetative propagation is possible.

Figure 6. Fruits of *Chamaerops humilis* (L. Mezzalana)

3.2.24. Cistus spp. *(C. incanus, C. monspelliensis, C. salvifolius)* (rockrose, cistus) - *(Cistaceae)*

The seeds are heat-resistant and tiny (1,000,000-1,300,000 seeds per kg in *C. incanus;* 1,250,000 in *C. monspelliensis;* 1,175,000 in *C. albidus;* 500,000 in *C. salvifolius).*

Rockroses are considered obligate post-fire seeders and they are therefore species that can germinate in great number in the post-fire period.

The plants are also highly inflammable and thus able to maintain the predisposition towards fire of the caenosis in which they abound.

Cistus albidus, C. incanus, C. monspelliensis and *C. salvifolius* rely solely on propagation by seed after fires. After the fire is over, the germinability of *C. albidus* and *C. monspelliensis* is 10 times higher than that recorded on land that has not been burned. High temperatures would have an important part to play in damaging the tough seedcoats, especially internal ones, which would seem to be decisive in the physical dormancy and in hindering moisture uptake. However, the seedcoats do not seem to be the only barriers to germination; another inhibitory mechanism might be the presence of phenolic substances, which could restrict the normal flow of oxygen towards the embryo. The wholeness of the seedcoats is compromised naturally as seed ages since germination can occur anyway in the absence of fires, several years after dispersal. This could explain the ability of C*istus* to colonise abandoned fields that are not subject to periodic fires.

With regard to the seeds of *C. incanus* and *C. monspelliensis,* exposure to temperatures of +120°C for 90 seconds in a kiln causes the seed seedcoats to split, and makes moisture absorption possible.

Fairly good results in the germination of *C. ladanifer, C. albidus* and *C. laurifolius* are achieved by using seeds soaked for 24 hours before sowing. Another treatment aimed at increasing the germination of *C. ladanifer, C. albidus, C. salvifolius* and *C. monspelliensis* consists in exposure of the seeds to temperatures in the range between +50°C and +100°C, preferably at 80°C, for 10-30 minutes (*C. monspelliensis* seems to be one of the most resistant to high temperatures). Finally, stratification of seeds in moist sand proves useful, subjecting the mass to +50°C for 3 hours at first, and then to temperatures between +2° and +5°C for a month (a cold moist stratification).

In spite of the resistance to high temperatures shown by the seeds, the optimum temperatures for germination are relatively low (around +17°C).

This could be interpreted as the species' adaptation to the Mediterranean climate, allowing the seedling to develop in cold, moist periods of the year (autumn, winter), when the risk of fires is minimal.

The seeds are collected in late summer, just before natural dispersal occurs.

The seeds can be stored for several years in dry conditions at room temperature.

It is advisable for them sow straight after the seeds have been collected, usually in September, followed by transplanting in spring. Seedlings should be protected in a cold tunnel during the coldest months.

Rockroses are easy to propagate by means of cuttings taken at the end of the vegetative season.

3.2.25. Colutea arborescens L. (bladder senna) - *(Leguminosae)*

Average germination: 70-80%

Number of seeds per kg: 55,000-96,000 (85,000)

Crop years are irregular, particularly in relation to attacks by insects. They may infest up to 40% of the seeds, therefore they must be disinfested before lengthy storage.

Sowing takes place in spring, using mechanically scarified seeds or seeds pre-treated with hot water (+80°C); although sowing with mechanically scarified seeds is to be preferred, for reasons of the operator's safety and of effectiveness of pre-treatment. In some cases, pre-treated seeds may germinate slowly (several weeks in environments kept at +20°C).

Propagation with semi-hardwood cuttings taken in summer is easy.

See *Leguminosae.*

3.2.26. Cornus mas L. (cornelian-cherry, corneliancherry dogwood) - *(Cornaceae)*
Average germination: 50-60%
Number of seeds per kg: 3,500-7,500 (000)
This species' seeds have a marked and complex dormancy. Even today, no really effective methods of hastening germination are known, but studies are being undertaken. In nature, germination occurs during the second spring or even during the third, after seed dispersal.
The seeds must be separated from the pulp of the fruits because it contains substances inhibiting germination.
Sowing takes place immediately after collection (early or mid autumn), or in late autumn, using seeds warm-stratified for 12-16 weeks. In the former case, germination does not take place during the following spring but in the second spring after sowing.

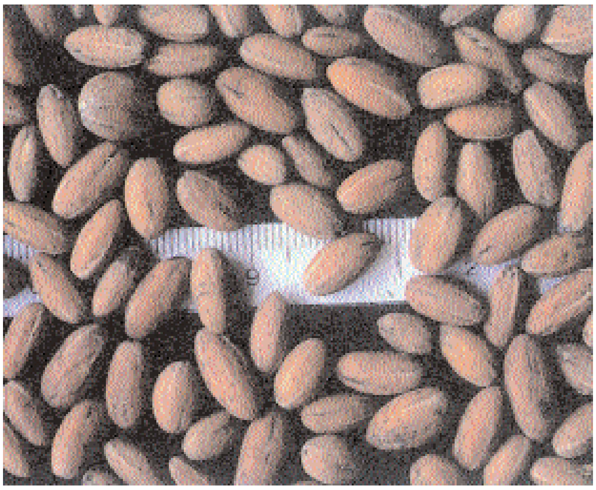

Figure 7. Seeds of *Cornus mas* (L. Mezzalana)

In the case of spring sowings, seeds warm-stratified for 16 weeks and then cold-stratified for 4-6 weeks have to be used. It may be useful scarify the seeds before the warm + cold stratification.
Vegetative propagation is possible by means of shoots or semi-hardwood cuttings (taken in July) or by grafting.

3.2.27. Cornus sanguinea L. (common dogwood, wild cornel) - *(Cornaceae)*
Average germination: 70-80%
Number of seeds per kg: 16,000-26,000 (20,000).
The seeds must be separated from the pulp containing substances that inhibit germination.
Autumn sowing is performed immediately after collection without any pre-treatment to the seeds while in spring sowings pre-treated seeds are needed (warm stratification for 8 weeks plus cold stratification for 8-16 weeks). In some cases, the warm stratification is not done; only the cold stratification is performed.
Scarification, performed before the other pre-treatments, may be useful. Germination may be very slow, especially in the case of old seeds.

3.2.28. Coronilla spp. (coronilla) - *(Leguminosae)*
This genus comprises 9 species, generally Mediterranean ones.
In *Coronilla valentina* subsp. g*lauca (=C. glauca),* germination is favoured by even temperatures between +15° and +20°C, with a 16 hours photoperiod. This characteristic indicates an adaptation strategy typical of those species in Mediterranean and/or desert environments that germinate in the coolest and dampest periods of the year.
With regard to *Coronilla valentina* subsp. g*lauca, C. juncea* and *C. minima,* the best pre-treatment for improving germination is mechanical scarification; this suggests that the cause of dormancy in these species is to be found in the toughness and impermeability of the seed-coat. On the other hand, application of gibberellic acid does not improve the germination and immersion in hot water may even turn out to be harmful. Thus, apart from the differences due to intraspecific variability, the pre-treatments aimed at improving the germination of *C. minima* and *C. valentina* subsp. *glauca* seem to be mechanical scarification followed by sowing in conditions kept at +15°C.
Soaking in tepid water for 12 hours before spring sowing is sometimes suggested for *C. varia.*
With regard to *C. emerus* (about 22,000 seeds per kg, with a germination average of 90%), mechanical scarification of the seeds is indicated, perhaps followed by soaking in tepid water for 1-2 hours before sowing. A short period of cold stratification following mechanical scarification may improve the rate of germination.

Spring sowing with mechanically scarified seed is to be preferred for the genus *Coronilla,* for safety reasons and for the effectiveness of the pre-treatment.
See *Leguminosae.*

3.2.29. Cotinus coggygria Scop. *(= Rhus cotinus* L.) (common smoke tree) - *(Anacardiaceae)*
Average germination: 80-90%
Number of seeds per kg: 75,000-115,000 (95,000-100,000)
The seeds have impermeable seedcoats and, moreover, they have an endogenous dormancy. Before spring sowing, mechanical scarification, or scarification with sulphuric acid (20-80 minutes) is suggested, followed by cold stratification for 60-80 days. Alternatively, summer sowing is possible, immediately after collecting the not completely ripe fruits.
Vegetative propagation by cuttings is possible.

3.2.30. Crataegus spp. (hawthorn) - *(Rosaceae)*
Average germination: limited if there is no seed pre-treatment.
Number of seeds per kg: 9,500-20,000.
Dispersal of hawthorn seeds is usually performed by birds, an evolutionary characteristic related to the marked dormancy of the seeds.
The seeds show the endogeneous type of dormancy, which may be removed by warm stratification for 4-16 weeks (usually 4-8), followed by cold stratification for 12-36 weeks (usually 12-16). Scarification before the warm + cold pre-treatments may be useful.
In nature, germination occurs during the second spring following dispersal. Some authors suggest scarification with sulphuric acid (from 30 minutes to 2 hours for *C. monogyna),* followed by 4 weeks of warm stratification and 12 weeks of cold stratification.
Spring sowing is usually preferred using pre-treated seeds.
After dormancy has been removed, germination of *rosaceae* species is usually favoured by marked daily alternating temperatures (for example, +25° during the day and +5°C at night), as it occurs in early spring in the Mediterranean areas.
Vegetative propagation is possible.

3.2.31. Cytisus spp. *(broom) - (Leguminosae)*
Spring sowing.
The seeds have a physical dormancy and therefore require pre-treatments that are able to scarify the tough external seedcoats. Spring sowing with mechanically scarified seeds is preferred, for reasons of safety and for the effectiveness of the treatment.
Vegetative propagation by cuttings is widespread.
See *Leguminosae.*

3.2.32. Cystus scoparius (L.) Link (Scotch broom) - *(Leguminosae)*
Average germination: 50-70%
Number of seeds per kg: 91,000-177,000 (125,000-130,000).
Spring sowing.
Besides the treatments described under *Leguminosae,* chemical scarification is suggested by means of immersion for 15-30 minutes in sulphuric acid; however, to ensure the operator's safety and the effectiveness of the treatment, spring sowing is preferred, using mechanically scarified seeds.
Vegetative propagation is possible.

3.2.33. Daphne spp. (daphne) - *(Thymelaeaceae)*
The genus *Daphne* comprises about 50 species, all of which are evergreen or deciduous shrubs. Only two of these are typical of Mediterranean climate environments, *D. gnidium* and *D. sericea.* There are other species in Italy in deciduous woods (*D. mezereum, D. laureola),* in Alpine environments *(D. alpina, D.cneorum, D. striata, D. pertea)* or, like *D. oleoides,* on crags and rocky pastures. Many species of the genus *Daphne* are ornamental plants that are generally propagated by vegetative means. In fact, they have adapted to life in particularly severe environments by developing physical characteristics (autogamy, cleistogamy, apomixis) which

have rendered them independent of pollination vectors thus favouring their propagation even in particularly difficult areas, but compromising the genetic variability of their progeny.
The *Daphne* plants are often propagated by vegetative means, because their seeds are considered deeply dormant. Information on the sexual propagation of these species, which is not much practised, is still scarce.
Recent studies on the dormancy of *Daphne* seeds have shown that it is possible to induce germination by pre-treating the dormant seeds with gibberellic acid (GA_3) and, simultaneously, with hydrogen peroxide (H_20_2) at low temperatures (pre-treatments applied singly have no effect). Therefore, temperature has a considerable influence on germination of the dormant seeds subjected to pre-treatment: at a constant temperature of +26°C, dormant seeds pre-treated with H_20_2 and GA_3 germinate rapidly in 28 days, but if the temperature is further reduced both the germination percentage and speed can be increased.
In the case of non-dormant seeds, which must not be pre-treated, a constant temperature of +25°C must be maintained to achieve germination. In fact, temperatures of between +15° and +30°C do not prove effective and germination is actually not recorded if the temperature is kept constant at +5°, +10° or +35°.
Complete germination of non-dormant seeds may also be achieved by alternating temperatures, i.e., keeping the seeds first at one temperature (+20°, +25° or +30°C) for 16 hours and then at another (+5°, +10°, +15°, +25° or +30°C) for 8 further hours. In short, the *Daphne* species with non-dormant seeds can be further characterised by taking account of the temperature at which they germinate; for example, there are species, such as *D. mezereum* that germinate at a wide range of temperature (between +5° and +25°C), while others germinate only if the temperature is higher than +15°C.
In order to test the germination percentage of the seeds of the various species of *Daphne*, the following procedure may be followed: the seeds must be soaked for 24 hours in a 1M solution of H_20_2, then in a 2000 ppm solution of GA_3 for 24 hours more, after which they must be cold-stratified (+3°/+5°C) for 56 days and, finally, tested for germination at +25°C. This procedure, devised for species of *Daphne* with different origins and belonging to different habitats, has proved to be particularly effective in promoting the germination of dormant seeds while it does not seem to harm the non-dormant ones.

3.2.34. Daphne gnidium L. (spurgeflax daphne) - *(Thymelaeaceae)*
Average germinatiomn:?
Number of seeds per kg:?
D. gnidium seeds do not show dormancy if they are collected (in the autumn) when still green, when they are fully developed but have not yet dried on the plant, and sown immediately. In these cases most of them germinate in the spring after they have been sown but sometimes another year is required. On the contrary, if stored seeds are used, they present a certain degree of dormancy that must be removed before spring sowing. Stored seeds of *D. gnidium* must, therefore, first undergo warm stratification for 8-12 weeks and, subsequently, cold stratification for 12-14 weeks. However, even in this case germination may begin a year after sowing.
After dormancy has been removed, the optimum temperature for germination is considered to be around +15°C. The young seedlings' root system is very delicate, so any transplanting must be undertaken with the greatest care and as soon as possible.

3.2.35. Daphne mezereum L. (mezereon, February daphne) - *(Thymelaeaceae)*
Average germination:?
Number of seeds per kg: 13,000
Warm stratification for 8–12 weeks is suggested for *D. mezereum*, followed by cold stratification for 12-14 weeks.
The seedlings must be transplanted as soon as possible.

3.2.36. Daphne sericea Vahl. - *(Thymelaeaceae)*
Average germination:?
Number of seeds per kg:?

Spring sowing is suggested, using seeds subjected to warm stratification for 8-12 weeks and to cold stratification for 12-14 weeks.
Vegetative propagation by cuttings is possible.

3.2.37. Elaeagnus angustifolia L. (Russian olive) - *(Eleagnaceae)*
Average germination: 50-60%
Number of seeds per kg: 7,400-15,400 (11,000-12,000)
The seed dormancy depends upon mechanical factors that block development of the embryo for a certain period; it also depends upon water-soluble inhibitors present in the seedcoat.
Warm stratification for 2-4 weeks (which some authors do not think is necessary) and cold for 4-12 weeks generally remove the dormancy (before spring sowings). Alternatively, spring sowing can be performed using seeds that have been soaked in running water (+15°C) for 6 days and subsequently coldstratified for 4 weeks. The use of peat as stratification medium increases the treatment's effectiveness. Since germination of the pre-treated seed is favoured by daily temperature ranges, sowing is performed at the end of winter-beginning of spring. If no pre-treated seed is available, sow in autumn.

Figure 8. Germinating seeds of *Elaeagnus angustifolia* (L. Ciccarese, APAT)

3.2.38. Erica spp. (erica, heather) - *(Ericaceae)*
The seeds are very tiny (several million per kg have been counted for *E. arborea*); they have no structures useful for wind dispersal but may be blown away by strong winds (usually for short distances).
The *Erica* genus is typical of the regions that are regularly scarred by fires. In fact, fire fulfils a basic role in stimulating the germination of these species. However, the mechanism by which fire acts upon germination, through the high temperature, smoke or aqueous smoke extracts, has not yet been fully investigated. In any case, it is certain that some of the *E. arborea* seeds in the ground manage to germinate even after being exposed to high temperatures (+120°C for 10 minutes), proving their adaptation to fires. Brief but repeated exposures to temperatures exceeding +70°C do, however, make the germinability decrease steadily. The lethal temperature for this species' seeds appears to start from +130°/+140°C. Moreover, considering the positive influence that cold stratification of the seeds (30 days) exerts upon germination, we may theorise that the seed of *E. arborea* also shows a physiological type of dormancy.
The substances left in the soil following the decomposition of vegetable matter may have negative effects upon the germination of other species (allelopathy). The leaves of *E. scoparia,* for example, contain various phenolic compounds that inhibit development of *Trifolium pratense.* However, the possible autotoxicity of such substances has not been clarified.
The seeds of about thirty South African species of heather respond very positively to exposure to the smoke obtained by burning plants of the characteristic flora of the *fynbos* (a region in South Africa with Mediterranean-type vegetation). Smoke is blown for 30 minutes over trays on which the seeds had been sown, inside a large canvas.
It is assumed that smoke is only one among many factors intervening in the promotion of germination in the case of those *fynbos* heathers that react less obviously to this treatment. Improved germination can be achieved for the seeds of these plants through exposure to smoke followed by warm + cold stratification.
Use of equipment specially designed to expose the seeds to smoke in order to stimulate germination of fire or smoke-dependent species is becoming widespread in Australia and South Africa.

A heat treatment has been described for *E. hebecalyx* in which the seeds are kept in *bain marie* (between +80° and +95°C for 3 minutes); this leads to a considerable improvement in germination.
After a smoke pre-treatment, the seeds of many heathers that are typical of the *fynbos* seem to react positively to marked daily temperature ranges (+25°C by day and +10°C by night). Numerous Mediterranean species that germinate in cool, moist seasons without any fires (autumn) may be favoured by comparatively low and constant temperatures (+15°C). Germination of *E. hebecalyx* is stimulated by exposure to light and constant temperatures (between +10° and +20°C); on the other hand, the process is partly inhibited if the imbibed seeds are placed in the dark. During germination, *E. arborea* seeds seem to be indifferent to exposure to the light, while alternating daily temperatures (+20°C by day and +15°C by night) favour the process.
One of the most likely effects of fire is to limit heather seeds' specific requirements of light and temperature, permitting germination under a wider range of conditions.
The seeds of many heather species, stored without any particular measures, maintain their viability for at least 3-7 years.

3.2.39. Euonymus europaeus L. (European euonymus, European spindle-tree) - *(Celastraceae)*
Average germination: 80%
Number of seeds per kg: 19,000-35,000 (28,000-29,000)
Sow in autumn, immediately after collection, without any pre-treatment or in spring using seeds warm stratified for 8-12 weeks and cold stratified for 8-16 weeks.
Vegetative propagation is possible.

Figure 9. Fruits and seed of *Euonymus europaeus* (L. Mezzalana)

3.2.40. Euphorbia dendroides L. (euphorbia) - *(Euphorbiaceae)*
Average germination: 60-80%
Number of seeds per kg: 160,000-170,000
Under natural conditions, euphorbia flowers in May-June and loses its leaves immediately after seed dispersal, in the hottest part of the summer. Germination is concentrated mainly in autumn; even if seeds are indifferent to light, satisfactory development of the seedlings requires high light levels.
The seeds have characteristics that identify them as belonging to the category of orthodox seeds. They have elaiosomes, special structures associated with dispersal by ants.
There is very little information regarding nursery growing. When seed was sown in autumn in a nontemperature-controlled greenhouse (no heating or air conditioning, windows open) with natural alternating day and night temperature, without any seed pre-treatment, a germination of 65% has been observed (viability determined by cut test was about 80%). The seeds were covered by a thin layer of soil (about 1 cm). Emergence commenced in the second week after sowing, reaching a peak during the third.
The influence on germination of exposing the seeds to smoke and to high temperatures (ovens) is being studied.

Figure 10. Euphorbias near Dorgali, Sardinia (P. Orlandi, APAT)

3.2.41. Ficus carica L. (fig-tree, common fig) - *(Moraceae)*
Average germination:?
Number of seeds per kg:?
The genus *Ficus* contains more than one thousand species, most of them tropical and sub-tropical.
The fig tree produces a false fruit (called syconium), an inflorescence which, after fertilisation, turns into an infruttescence containing 'seeds' (actually fruits) that are tiny drupes.
In natural conditions seed dispersal relies mainly on birds, which are particularly attracted by the sweet, edible pulp of these fruits. Thus birds are the dispersal agents, but they also act as germination agents: they are attracted by the fleshy red pulp and feed on it, freeing the seeds completely, thus even any inhibiting effects that may be present are eliminated. Otherwise, if the seeds remain inside the syconium, the microenvironment is extremely hostile to germination, owing to the high concentration of sugars that involve a high osmotic pressure. However, the seedcoats of the seeds ingested by birds are not corroded by the digestive enzymes. Germination of the 'seeds digested' by birds occurs in typically Mediterranean conditions: with a temperature ranging between +10° and +30° C, at constant humidity and without any dependence upon light.
In Mediterranean climatic environments the seedlings originating from seeds just deposited by the birds may have a continuous growth, while in the parts of the Mediterranean closest to continental Europe the seeds dispersed by birds survive the winter season in a quiescent state and recommence their physiological activity only in the following spring, when the temperature is more suitable for germination.
In order to obtain good quality seeds, the fruits must be collected when they have become a yellowish-brown and immediately afterwards they must be crushed and soaked in water. Then seeds must be recovered and air-dried for several days in a shaded environment. Before sowing, it is useful to soak the seeds for 10 minutes in hot water (+40°C to +60°C). It is advisable to cover the seeds with a thin and light layer of substrate.
Shade is necessary during germination.
Vegetative propagation is commonly adopted.

3.2.42. Fraxinus spp. (ash) - *(Oleacea)*
Seeds of the genus *Fraxinus* show various types of dormancy. For example, *F. excelsior* has one of the most complex dormancies, resulting from various interactive factors: dormancy due to the incomplete development of the embryo; embryonal dormancy due to the presence of inhibitory effects caused by the pericarpal tissues. Since the physiology of the factors involved in the dormancy of the various species is not perfectly known, and given its great variability due to provenance and the means of collection and storage of the fruit, the pre-treatment suggested by the literature has not always proved effective.
To avoid loss of quality during storage, it is advisable to bring the seeds down to a moisture content of around 8-10% and arrange them in temperature-controlled environments at +4°C in airtight containers. The seeds of some species (*F. excelsior, F. angustifolia)* may be stored in a non-dormant state, after they have been subjected to pre-treatments to remove dormancy and subsequently dried to about 8%.

Propagation of ash-trees by cuttings is not practised, owing to the difficulty of rooting most of the species. Only *F. excelsior* provides reasonable results. Grafting, on the contrary, is practised to propagate selected varieties of a number of species.

3.2.43. Fraxinus angustifolia Vahl. (narrow-leaved ash) - *(Oleaceae)*
Average germination: 60-80%
Number of seeds per kg: 10,000-20,000 (11,000-14,000)
Autumn sowing without any pre-treatment or spring sowing of seeds subjected to one of the following treatments:

a) 4 weeks of warm stratification + 4-8 weeks of cold stratification; or
b) 16 weeks of cold stratification.

After dormancy has been removed, germination is favoured by marked daily alternating temperatures of +25°/+5°C (warm by day, cold by night). Under natural conditions these correspond to late winter-early spring. Constant temperatures of +20°C induce secondary dormancy in non-dormant seeds, therefore late sowings, when the soil temperature is high, are to be avoided.
The seeds of *F. angustifolia* may be stored in a non-dormant state, after they have been subjected to pre-treatments to remove dormancy and subsequently dried to about 8%.
See *Fraxinus* spp.

3.2.44. Fraxinus ornus L. (flowering ash, manna ash) - *(Oleaceae)*
Average germination: 60-80%
Number of seeds per kg: 36,000-50,000 (42,000-43,000)
Autumn sowing, without any pre-treatment to seeds, or spring sowing using seed warm stratified for 2-8 weeks (usually 3) and afterwards cold stratified for 8-15 weeks.
After dormancy has been removed, germination is favoured by marked alternating temperatures of +25°/+5°C (warm day-cold night), which corresponds under natural conditions to late winter-early spring. Constant temperatures of +20°C may induce secondary dormancy in non-dormant seeds and therefore late sowing, when the soil temperature is high, is to be avoided.
See *Fraxinus* spp.

3.2.45. Genista spp. (broom) - *(Leguminosae)*
The genus *Genista* comprises more than 200 species.
Besides the treatments described in the notes referring to the family of *Leguminosae*, to scarify the seedcoats of some species of the genus *Genista* (*G. germanica, G. hispanica, G. pilosa),* some authors have advised chemical scarification with sulphuric acid for 30 minutes, followed by prolonged washing. Cold stratification for 3 months has also been suggested for *G. tinctoria* (300,000 seeds per kg).
For staff safety reasons and for effectiveness of the treatment, spring sowing is preferred, using mechanically scarified seed.
Vegetative propagation by cuttings and by grafting is widespread.
See *Leguminosae.*

3.2.46. Glycyrrhiza glabra L. (liquorice, licorice) - *(Leguminosae)*
Average germination:?
Number of seeds per kg:?
In natural circumstances, propagation is predominantly vegetative. In fact, the species is characterised by a large root system that is widely employed for vegetative propagation (pieces of stolon or root).
Even though the inflorescences consist of numerous flowers (40-70), few of them develop fruits which seeds show low viability.
Sowing takes place in spring with seed that has been scarified or pre-treated with hot water.
See *Leguminosae.*

3.2.47. Helichrysum spp. (helichrysum, everlasting) - *(Compositae)*
The genus *Helichrysum* includes a vast number of species (about 300), twenty-five of which grow wild in the Mediterranean region (*H. italicum* and *H. stoechas* are among the most widespread in the Italian Mediterranean areas). The fruit is usually a tiny achene (more than 1,000,000/kg; *H. stoechas* can reach up to 10,000,000/kg) with a deciduous pappus that facilitate wind dispersal.
They propagate by seed extensively, often covering wide areas. They show considerable ability in colonising inhospitable habitats (steep slopes, coastal dunes, abandoned fields, pastures, etc.).
There do not appear to be any problems of dormancy in the Mediterranean species of *Helichrysum*, even though in some cases their seeds could benefit from a short period of cold stratification. Under optimum conditions, the seeds rapidly begin to germinate and after only 48 hours the first radicles can be seen. A constant temperature of +20°C, in the dark, seems to be the ideal condition for achieving good germination. Alternating temperatures of +20°/+10°C are advised for the Australian species *H. apiculatum*, on the contrary. Like many perennial Mediterranean species, the germination of *H. stoechas* occurs in autumn; the germinability can exceed 90%. *H. scorpioides,* which grows wild in Spain and shows physiological dormancy, germinates well at +20°C, either in the light or in the dark, while *H. cassinianun*, wild in Australia, germinates best at temperatures between +15° and +20°C; it definitely needs light.
Judging from the seed's characteristics, it may be assumed that storage for lengthy periods is possible (orthodox behaviour).

3.2.48. Hippophaë rhamnoides L. (common seabuckthorn) - *(Eleagnaceae)*
Average germination: 75%
Number of seeds per kg: 55,000-130,000 (90,000).
After they have been collected, the seeds are recovered by macerating the fruits.
Sowing takes place in autumn without any pre-treatment to seeds or in spring, using seeds that have been cold stratified for 4-12 weeks. After the third week of cold stratification it is advisable to check the state of the seeds within the stratification medium as they can germinate at low temperatures.
Chemical scarification with sulphuric acid for one minute is an alternative pre-treatment for spring sowing (the operation must be performed with the greatest possible care). Following this, the seeds are washed thoroughly.
After dormancy has been removed, germination is favoured by temperatures close to +20°C.
Vegetative propagation may be accomplished by root cuttings, semi-hardwood cuttings and by root suckers.

3.2.49. Inula viscosa (L.) Aitan (inula) - *(Compositae)*
Average germination:?
Number of seeds per kg:?
Information is only available on vegetative propagation by cuttings.
Semi-hardwood cuttings are collected at the end of the summer and are planted immediately afterwards in containers, in shaded environments (tunnels). A very high rooting percentage is usually achieved.

3.2.50. Laurus nobilis L. (laurel) - *(Lauraceae)*
Average germination: 75-85%
Number of seeds per kg: 1,000-1,100
Number of fruits per kg: 600-1,500
Laurel is a dioecious plant, whose fruit is a drupe with a single seed of 1-1.5 cm diameter. Seeds show a recalcitrant behaviour, desiccation below 15% results in complete loss of viability. At seed dispersal moisture content is about 37-40%.
After collection (autumn) of fully ripe fruits, they are usually soaked in water for about 10 days to remove the fleshy pericarp that encloses the seed and is a cause of dormancy (even if it is not the only one). A cold stratification for 6-8 weeks removes other types of dormancy.

Autumn or winter sowing, without any pre-treatment, or spring sowing with pre-treated seeds. After dormancy has been removed, alternating temperatures of 20°C (16 hours with light) and 16°C (8 hours in the dark) seem to stimulate germination
Vegetative propagation is possible.

3.2.51. Lavandula spica L. (lavender) - *(Labiatae)*
Average germination:?
Number of seeds per kg: 1,000,000
The seeds germinate without any pre-treatment. Germination is favoured by temperatures ranging from +15 to +25°C.
Vegetative propagation is very widespread.

3.2.52. Lavandula stoechas L. (wild lavender, French lavender) - *(Labiatae)*
Average germination: usually low.
Number of seeds per kg:.?
Sown in autumn without any pre-treatment.

3.2.53. Lavatera arborea L. (bushmallow, tree mallow) - *(Malvaceae)*
Average germination: 80%
Number of seeds per kg:?
The seeds of many species living on steep cliffs above the sea and in the dry parts of shoreline slopes prove to have a physiological dormancy. On the contrary *L. arborea, L. cretica* and *L. oblongifolia* have been shown to have impermeable seedcoats (physical dormancy, which is eliminated by scarification). It may be supposed that a short period of cold stratification may improve the percentage of germination of these three species.
Photothermic cycles of 14 hours of light at +20°C and 10 hours of darkness at +10°C, but also constant temperatures of around +20°C, have positive effects on rate and speed of germination. The germinative process is negatively affected by absence of light, such as might be the case with seeds covered by too much soil. Seeds that have not germinated in the dark may germinate when they are brought into the light (photoperiods of 12-14 hours).
Since *L. arborea* can germinate on sea-shore slopes, it may be supposed that it has a high degree of tolerance to salt, as is the case with other species typical of such environments.

3.2.54. Leguminosae
This botanical family has been recently divided into *Fabaceae*, *Cesalpiniaceae* and *Mimosaceae* but, to simplify reading, the old systematics will be considered in this text.
This family, represented by many species of trees and shrubs in the Mediterranean flora, is characterised by its capacity to actively fix the atmospheric nitrogen (N_2) by means of symbiosis with the nitrogen fixing bacterium *Rhizobium*. All species of the genus *Rhizobium* are aerobic and can survive saprophytically in the ground until they enter into contact with the roots of a leguminous plant with which symbiosis is possible. In this case, the *Rhizobium* penetrates the root at the level of the root hairs and proliferates, forming nodules where the bacteria supply the plant with nitrogen and the plant supplies the bacteria with carbohydrates.
Symbiosis may be promoted by inoculating the seeds; it gives a higher survival rate among the seedlings after they have been planted out and a steady growth, resulting in a better response to competition and field performance. The taxonomy of the genus *Rhizobium* is not yet clear, but it is certain that there is a specificity between species of *Rhizobium* and species of *Leguminosae*. Furthermore, within the framework of a determined species of *Rhizobium*, it is possible to identify numerous races that prove to possess a diversified efficiency in assimilation and transfer of nitrogen.
Legume seeds are characterised by extremely tough and impermeable seedcoats that hinder germination, since they prevent moisture absorption. For example, in *Acacia senegal* the outside seedcoat (testa) is formed of three layers of cells, each of which has a specific ecophysiological role to play in the moisture uptake. In the natural state, the impermeability decreases with the passage of time and also because of the environmental factors that operate by scarifying the seedcoats. Within one seed lot of a determined species, there is a marked va-

riability between one seed and another as far as the toughness of the seedcoat is concerned. This feature, which may be considered an adaptation for survival, under natural conditions enables the formation of soil seed banks so that germination occurs over a long period.
Hardseededness makes it possible to store legume seeds for a long time as well, even under far from ideal conditions.
In order to achieve simultaneous germination, one of the most common methods employed to undermine the integrity of the seedcoats is to soak the seeds in water at a high temperature for 12-24 hours. The source of heat must be removed before pouring the seeds into the water; the mass, consisting of ten parts of water to one part of seeds, must be stirred from time to time until it is cold. Once it has been removed from the water, the seed is dried in a ventilated area, but must not be exposed to the sun, and sown as soon as possible. The treatment is not devoid of danger for both the operators, especially when there is a considerable quantity of hot water, and also for the seeds, because the ones with the thinnest seedcoats may be damaged; they are thus subjected to genetic selection that favours the seeds with the tough seedcoats. Alternatively, chemical scarification may be employed using acids or alkalis, or mechanical scarification using appropriate machines. The former is not advisable, because of the risks connected with handling corrosive substances, and also because of the possibility of harming the seeds with thinner seedcoats; the latter - mechanical - operation is simple and efficacious but almost unknown in Italy.
There is a voluminous bibliography available on scarification performed with acids and boiling water. It is advisable, however, to check the validity of the techniques described, by means of preliminary tests performed on small samples of seed since heterogeneity in the toughness of the seedcoats is considerable, both between different species and also within the context of a single species (even between seed lots of the same provenance), while information on the treatments to be employed may seem contradictory.
Mechanical scarification is carried out with equipment consisting of a metal cylinder, lined internally with sandpaper, and a series of central blades that revolve at a high speed propelling the seeds against the walls, thus scarifying the seedcoats; the embryo is damaged only rarely. The most suitable kind of sandpaper and the optimum duration of the scarification must be established for each sample; at a rate of 1,200 rpm the operation does not usually exceed 60 seconds. To test the effectiveness of the treatment, after the preliminary scarification test the seeds are soaked in water and after several hours the percentage of imbibed seeds is estimated: i.e., the ones that appear to be swollen. If imbibition has occurred, then it means that the seedcoats have been scarified.
Mechanical scarification can increase the speed of germination considerably. It is also possible to store for at least 18 months seeds that have been mechanically scarified, without any loss of viability, as has been proved with *Acacia saligna, Ceratonia siliqua, Laburnum anagyroides* and *Robinia pseudoacacia.* Seeds that have been scarified with sulphuric acid, can be stored for about 8 months, as demonstrated with *Cytisus scoparius, Laburnum anagyroides* and *Robinia pseudoacacia.* After having been soaked in the acid, the seeds must be thoroughly washed in order to remove any traces of acid and then dried. Certain conditions are necessary so that the quality of scarified seeds is not altered during storage; such conditions include the moisture content of the seed, which must not exceed 10%, the temperature of the cold store, which must vary between –3° and +3°C, and the type of container, which must be airtight or vacuum packed.
To sum up, the seeds of most legume trees and shrubs may be sown in spring following one of the following pre-treatments: a) soaking in water at high temperature; b) soaking in concentrated sulphuric acid (followed by washing in cool water for 24 hours); c) mechanical scarification.
Spring sowing using mechanically scarified seed is to be preferred, for reasons of staff safety and effectiveness of the treatment.

3.2.55. Lembotropis nigricans (L.) Griseb (black broom) - *(Leguminosae)*
Average germination:?
Number of seeds per kg:?
Spring sowing uses mechanically scarified seed or seed pre-treated with hot water. Spring sowing using mechanically scarified seed is to be preferred, for reasons of staff safety and effectiveness of the pre-treatment.

3.2.56. Ligustrum spp. (privet) - *(Oleaceae)*
Average germination: 70-90%
The size of the seeds varies according to the different species (in *L. vulgaris* there are 50,000-68,000 seeds per kg, while in *L. japonicum* there are 45,000-100,000).
The oily pulp is generally removed from the fruits by maceration before they are sown or stored. Sowing is done in autumn immediately after collection, without any pre-treatment, or in spring using seeds that have been cold stratified for 4-12 weeks. Young seedlings are very often transplanted into containers after they have been grown in seedbeds.
Vegetative propagation by cuttings is widespread.

3.2.57. Lonicera spp. (honeysuckle) - *(Caprifoliaceae)*
The genus *Lonicera* comprises a large number of species (more than 180), all of which are shrubby and more or less voluble originating from different continents. Their fruits are small berries containing few to many seeds that are dispersed by birds, rodents and other small mammals. The seeds of some species ripen in summer while others disperse in autumn; they must be extracted from the berries by macerating them in water. Seeds are considered orthodox because they are able to maintain viability for a long time if they are dehydrated and stored in airtight containers at +4°C. *L. etrusca* and *L. implexa* contain a number of seeds per kg that varies from 100,000 to 110,000.
Not much information on the average germination of this genus is available, but in the case of *L. fragantissima* (native to Eastern China), *L. japonica* (native to Eastern Asia), *L. involucrata* (native to the United States)*, L. maacki* (native to Russia) and *L. morowii* (native to Japan) it is estimated at over 80% (sometimes 100%). With the exception of only a few species (*L. dioica, L. canadensis, L. hirsuta),* the majority of the *Lonicera* spp. show different types of dormancy that are closely related to their dispersal patterns (i.e. if they are exposed or not to long warm periods after they are dispersed). The dormancy, that can vary within a given seed lot (some seeds show dormancy while others are completely non-dormant), in a number of species can be interrupted by cold stratification for 4-12 weeks (4 weeks for *L. tatarica*, 12 weeks for *L. japonica* and *L. xylosteum).* Some species (*L. fragantissima, L. hirsuta, L. oblongifolia),* need a period of warm stratification (8 weeks) prior to cold stratification, especially those that are naturally exposed to warm temperatures after seed dispersal in summer; these species are characterised by having underdeveloped embryos as well.
After dormancy has been removed, some species (*L. japonica, L. maacki, L. morowii)* germinate better in light than in darkness.
Autumn sowing is done immediately after collection without any pre-treatment to seeds. For spring sowings pre-treated seeds are used.
Under natural conditions vegetative reproduction takes place through the formation of new roots that come from knots in the stems.

3.2.58. Myrtus communis L. (myrtle) - *(Myrtaceae)*
Average germination: 50-80%
Number of seeds per kg: 150,000-250,000
The fruits must be collected when they are completely ripe (November-December). It is advisable to remove the fleshy pericarp that encloses the seed immediately after collection in order to free the seeds and then complete the operation by washing to eliminate the empty seeds, which float. Once they have achieved a low moisture content and have been placed in airtight containers, the seeds can be stored for several months.


Figure 11. Seeds of *Myrtus communis* (L. Mezzalana)

Although it is not indispensable, a short period of cold stratification of the seeds (3-6 weeks) favours a more complete and simultaneous germination.
Sowing generally takes place in late autumn, immediately after collection, without any pre-treatment of seeds. Alternatively, it may be performed in spring, using cold-stratified seeds.
Considering their tiny size, the seeds ought to be covered with a very thin layer of porous and light substrate that makes it possible for the light to stimulate germination. The seeds are very often sown in seedbeds and then transplanted in containers or in open seedbeds.
Seedling early development is rather slow and subsequent transplanting leads to considerable stress; therefore 60% shade is often applied in the nursery in spring and summer.
Vegetative propagation by cuttings is possible; they have to be collected in summer.

Figure 12. Flowering of *Myrtus communis* (P. Orlandi, APAT)

3.2.59. Nerium oleander L. (oleander) - *(Apocynaceae)*
Average germination: 70-80%
Number of seeds per kg: 200,000-230,000
After the first intense cold spells in winter, the brown fusiform fruits open allowing dispersal of the numerous villous seeds that have a tuft of hairs on the top. Collection is easy.
There is no information on the storage behaviour of the seeds, but their characteristics lead one to suppose that they are orthodox.
If sowing is performed on a well-drained substrate in environments with a temperature of around +20°C, germination does not pose any particular problem; it begins after 7-10 days. There is sometimes a high percentage of seedlings lacking in chlorophyll (albinos).
A short cold stratification (7-10 days) can contribute to simultaneous germination.
Given the size of the seeds, it is advisable to cover them after sowing with a very thin, light, porous layer which permits light to pass through and favours germination.
Vegetative propagation by cuttings is usual.

Figure 13. Seeds of *Nerium oleander*, excluding hairs length is 5 mm ca.
(B. Piotto, APAT)

3.2.60. Olea europaea L. subsp. *sativa* Hoffm. et Link = *Olea europaea* L. subsp. *europaea* (olive tree) - *(Oleaceae)*
Average germination: very variable (5-90%)
Number of seeds per kg: 1,000-4,400
Few plants like the olive tree (*Olea europaea* L. subsp. *sativa* Hoffm. *et* Link = *Olea europaea* L. subsp. *europaea)* have been so involved in the history and culture of the Mediterranean

Size and yield of fruits and stones			
Type of fruit	Number of olives per kg	kg of stones per ton of olives	Number of stones per kg of olives
Small	700	145	4,400
Medium	200	110	1,650
Large	100	90	1,000

peoples. Originating from Asia Minor (Iran, Iraq, Syria, Turkey), the olive tree was introduced into Lebanon, Palestine, Egypt, Greece, Italy and the whole Mediterranean basin, where it has been cultivated since ancient times. The geographical range of distribution of this species is very vast, from the centre-south of France to the areas just north of the Sahara; thus, the plant has adapted to different soil and climate conditions and shows marked diversity, including features relevant to the biology of the seed. Therefore the information provided in this work cannot be generalised for the numerous ecotypes and commercial varieties, but must be taken as notes of guidance.

Figure 14. Flowering of olive trees (B. Piotto, APAT)

Under natural conditions, the first fruitings occur roughly after the tenth year from germination. Birds *(Erithacus rubecula, Sylvia melanocephala, S. atricapilla, Turdus philomelos,* etc.) are the main agents for dispersal; they ingest the whole fruit or, if it is particularly large, they eat the pulp. Birds that feed on the fruits of the olive and the wild olive trees as a rule also eat those of the *Phillyrea* spp. and so the presence of both genera at only one site reduces the removal of fruits on the cultivated olive trees. The germination of the seeds of numerous species of the *Oleaceae* family improves after they have passed through a bird's digestive system.
Cultivars of olive trees are propagated mainly by vegetative means. In Italy, plants obtained by either cuttings or grafting on wild olives are widely used. In the opinion of many olive farmers graftings are more suitable for arid zones, especially after outplanting, when the taproot allows a deeper penetration into the ground. For this reason propagation by seed is widely employed for the production of graft rootstocks; it also plays an important role in maintaining genetic diversity, in genetic improvement for the breeding of new varieties and, together with the wild olive (*Olea europaea* L. subsp. *oleaster* Hoffm. *et* Link = subsp. *sylvestris* Miller), in obtaining plants to be used in landscaping and the restoration of degraded Mediterranean areas. The strategy the species employs for regeneration and long-term survival seems to consist in creating soil seed banks and in the erratic germination of the seed over a prolonged period (2-4 years). The 'stones' (seeds enclosed by the woody endocarp) of several cultivars (Dolce di Rossano, Carolea, Tondina and Grossa di Cassano), sown between September and January, germinate throughout a lengthy period, with peaks concentrated mainly at three times after sowing: an early one between the 70th and the 150th day, a second peak between the 300th and 400th day, when most of the viable seeds germinate and, finally, the third one occurring at about the 800th day. To a great extent, germination occurs during the spring and the autumn that follow the natural dispersal.
The germinability, for some commercial varieties at least, seems to be linked to the total amount of carbohydrates in the seed (embryo and endosperm). The best period for collecting olives for sowing should, therefore, coincide with the time of year when the greatest concentration of these substances is to be found; that is, usually between the end of November and the beginning of December.
Germinability, although strictly linked to the seed's degree of ripeness and to the cultivar, also depends upon the conditions and length of storage.
Although there have been no specific experimental tests, nursery practice has often met with

low germinability (5-10%) in commercial varieties characterised by large fruits, compared to those with small fruits. In the latter case, germinability may exceed 90%. This is why the small-fruited varieties are preferred in the production of rootstocks. In Italy, for example, seeds of the cultivars Canino, Maurino, Mignolo, Americano and Moraiolo are widely used for this purpose. The following table gives the size and yield of olives and stones in relation to small, medium or large fruits.

The percentage of empty seeds is higher in the drupes collected at the beginning of fruits' colour change (September) and is lower in ripe ones (December); this is, above all, because the drupes containing empty seeds tend to fall off in the meantime. Generally speaking, the percentage of ripe drupes with empty seeds lies between 13 and 17% and seldom exceeds 20%, but in the Mignolo variety it may even reach 30%.

In nature, germination is regulated by the presence of a dual form of dormancy. The woody endocarp (stone) offers mechanical resistance (exogenous dormancy), while inhibiting substances, presumably localised in the seedcoats (testa) and in the endosperm, may interfere in the embryonal germination even after the dormancy imposed by the woody endocarp has been removed. Actually, experiments have shown that the naked embryo does not seem to be affected by any form of dormancy and germinates rapidly after 10-14 days of *in vitro* culture, while the whole seed (embryo, endosperm and seedcoats) may be effectively stimulated in its germination by treatments with ethylene-promoters and cytoquinines. Removal of the woody endocarp favours germination of the seed also because it allows a more complete water uptake and oxygenation of the embryo. It should also be noted that embryonal dormancy would seem to decrease over time and disappear completely in stones stored for 4 years. As regards the role of temperature on dormancy and germination, it has been observed that embryos of the cultivar Chalkidikis grown *in vitro* at +20°C have achieved germination levels up to 73%, while the ones previously undergoing cold stratification (+10°C) for at least 2 weeks germinated more completely (96%). The whole seeds (embryo, endosperm and seedcoats), however, do not germinate if they are kept at a constant temperature of +20°C, while germination occurs following cold stratification (+10°C) for 3-4 weeks. These results would seem to indicate the existence of germination inhibitors, more evident in the structures close to the embryo than in the embryo itself. Cold-moist conditions reproducing what occurs in nature during winter might act by removing the germination inhibitors.

No matter how useful it may be, removal of the endocarps cannot be widely employed in traditional nursery practice since it is an excessively laborious, time-consuming and tiresome operation. Moreover, seeds lacking the endocarp are more subject to fungal infections and are not easy to handle. In the nursery, the practical alternative to mechanical removal of the endocarp

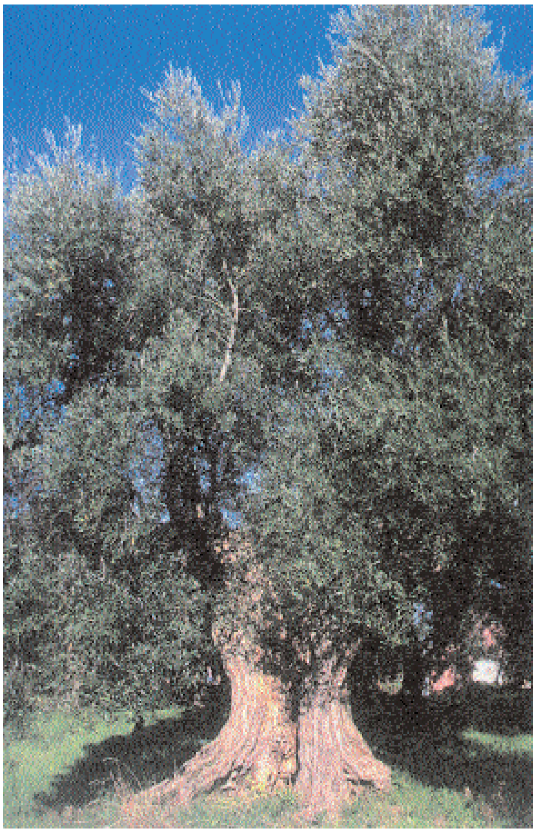

Figure 15. Olive tree near Rome (P. Orlandi, APAT)

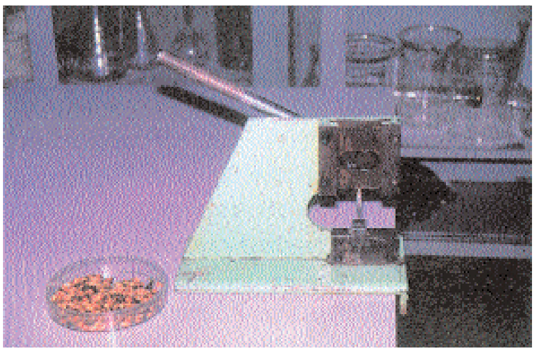

Figure 16. Laboratory device used to crack the woody endocarps of olives (M. Lambardi, CNR)

consists in autumn sowing of the stones, either without any pre-treatment or after soaking in sodium hydroxide or concentrated sulphuric acid (chemical scarification) and subsequent washing for 2 hours. Experiments using this caustic substances indicate that scarification times may vary according to the different cultivars. For example, 24 hours soaking in sulphuric acid is suggested for the Redding-Picholine variety. In this way complete germination may be obtained in the spring following seed collection. An alternative, or complement, to chemical treatment consists in cold stratification of the stones at +5°C for a period varying between 1 and 8 months. It should be noted that mechanical scarification of the endocarp (by means of electrically operated equipment that produces abrasions) could prove to be a valid alternative to chemical scarification.
To obtain olive seedlings destined for use as rootstocks, some nurserymen at Pescia (Italy), in accordance with an old nursery-olive growing tradition, adopt a technique that envisages autumn collection (November) of olives of cultivars with small fruit, followed by careful removal of the pulp by passing the fruit through stalk-stripping machines (normally used to separate grapes before preparing wine, adapted *ad hoc*). After a complete cleaning the stones by mixing them in a cement-mixer with caustic soda (1 kg of soda to 100 kg of stones) or by cleaning them in a 10-20% solution of calcium hydroxide and repeated rinsing, the stones, without pulp or grease, are stored in cool, dry conditions where they dry naturally. In June-July the following year the stones are rehydrated by soaking in water (changed every 2 or 3 days) for a total of about 20 days. They are subsequently drained and treated with 300 g/hl of fungicide in powder, (Thiram, active ingredient 49%) and mixed with sand. They are then stratified in the open air in cool places inside large perforated tanks that ensure drainage. The upper part of the tanks may be covered by insulating material (dry leaves, hessian, cloth, jute sacks) while the stones must be kept moist and aerated. This operation is sometimes performed without a stratification medium (sand); in this case the 'naked' stones tend to lose moisture easily. In September, after a second treatment with fungicide, sowing takes place (3000 seeds/m^2, corresponding to 2-3 kg of seed/m^2) in raised benches in unheated plastic tunnels. The substrate covering must be light and friable.
In order to improve germination percentage, empty stones are separated by floating them in water or in a 30% (weight/volume) solution of sodium chloride; this is performed before either pre-sowing treatments or sowing. In practice, the nurseryman recognises when germination is near because the stones become darker and swell up. Furthermore, the seedcoats (inside the stones) take on a particular green colour, different from the initial brown.
Germination begins in November, about two months after sowing, and continues until December-January. At the end of winter (February) a resumption of the germinative processes often occurs involving the most dormant seeds. As a result of this, the late germinating seedlings tend to be smothered by the earlier ones. In April the seedlings, which are usually 5-10 cm tall by now, are pulled up and arranged with bare roots in boxes lined with plastic film to be transferred to the nurseries which will grow them, in open beds or in containers, until they are ready for the graft. Grafting is performed the year after, when the seedlings are 30-40 cm tall. In the case of the cultivar Mignolo, the yield in seedlings is usually 50% of the seeds collected: this is due to the fact that up to 30% of the stones contain empty seeds and a further 20% rot in the period between stratification and complete emergence.
The stones of *Olea cuspidata*, a species similar to *Olea europaea,* used as rootstock in many countries (India and China, for example), respond positively to chemical scarification pre-treatments with sulphuric acid (5-10 minutes) or to soaking in a 3% solution of Na_2CO_3 for 5 hours, followed by immersion in a 0.5% solution of KOH for 6 hours. In both cases, a germination exceeding 70% is achieved. Other experiments with species of the genus *Olea*, such as *O. cuspidate* Wall., *O. asiatica* Desf. and *O. ferruginea* Royle, suggest that seeds which have had the woody endocarp removed germinate rapidly without any pre-treatment, always provided that they come from ripe fruits and are sown immediately after collection.

3.2.61. Opuntia ficus-indica (L.) Miller (prickly-pear) - *(Cactaceae)*
Average germination: 50-90%
Number of seeds per kg: 49,000-55,500
Besides *O. ficus-indica,* which is one of the most widespread species in the genus, other species extensively found in the Mediterranean include *O. basilaris* (62,000 seeds/kg), *O. dilleni* (107,000 seeds/kg), *O. lindhemerii* (46,000 seeds/kg), *O. littoralis* (42,000 seeds/kg), *O.*

polyacanta (44,500 seeds/kg), *O. rastrera* (63,500 seeds/kg), *O. soherensis* (48,000 seeds/kg) and *O. sulphurea* (51,500 seeds/kg). Introduced into Europe in the 15^{th} century, *O. ficus-indica* is a species that tolerates extremely dry conditions. It is not invasive, especially in the case of the form without prickles (*O. ficus-indica* forma *inermis)*, and it lends itself to a number of uses. It is used for food, to create hedges, for breeding cochineal insects for the production of carminic acid, as fodder for livestock in periods of extreme drought, to combat erosion and to reclaim degraded areas. In its natural state it provides shelter and food for the wild fauna. Plantations and hedges of this species cover about one million hectares in the Mediterranean basin.
In Mediterranean areas the simultaneous presence of high temperatures and drought during the summer favours vegetative propagation. On the other hand, relatively low temperatures during the autumn, just after the fruits have ripened, limits germination of the seeds.
The species also shows a number of biological mechanisms, such as cleistogamy, apomixis as well as polyploidy, that reduce the chances of sexual propagation.
Ripe seeds are collected, washed, dried and stored without the need for any special measures. With regard to links between storage and germinability of the seeds, some authors advise that the highest germination percentage is not achieved before 12-14 months after collection. Under controlled conditions (12 hours photoperiod with temperatures between +20° and +30°C) germination, which commences after a few days, may be as high as 90%. Polyembryony (generally speaking there are no more than 4 embryos per seed) may occur in as many as 50% of the germinated seeds.

3.2.62. Ostrya carpinifolia Scop. (European hophornbeam) - *(Corylaceae)*
Average germination: usually lower than 50%
Number of seeds per kg: 100,000-333,000 (167,000-190,000).
At a moisture content of 10%, the seed stores well for 1-2 years (and longer) at low temperatures (between -7° and -5°C) in airtight containers.
Sowing is performed in late winter-early spring with seeds warm stratified for 4-8 weeks (4 should be sufficient for more southerly provenances) and cold stratification for 16-23 weeks. Before commencing the pre-treatments, it is advisable to immerse the seeds in water in order to separate the empty seeds, which will usually float.
Hophornbeam seeds will usually germinate at low temperatures, therefore it is advisable to check the stratification medium frequently towards the end of cold stratification. The germination of pre-treated seed (non-dormant seeds) is encouraged by marked alternating temperatures (low temperatures by night and high by day). Therefore sowing is to be avoided in periods when the night-day temperature range is not sufficiently marked (such as late spring or early summer when the ground temperature is rather high).

3.2.63. Osyris alba L. - *(Santalaceae)*
Average germination: in some cases it reaches 80%
Number of seeds per kg:?
This is a semi-parasitic dioecious species.
The fleshy fruits are collected when they are completely ripe at the end of summer, the pulp has to be removed shortly after.
Sowing is done in seedbeds immediately after collection. During the coldest months protection in a cold tunnel is required.

3.2.64. Paliurus spina-christi Miller (Christ's thorn) - *(Rhamnaceae)*
Average germination: 70-80%
Number of seeds per kg: 65,000
Fruits are generally collected in autumn and sometimes subjected to a hammer mill to break the very hard exocarp and extract the seeds (every fruit has 3).
Seeds show physical dormancy due to the hard seedcoats that prevent water uptake. Seedcoats can be eroded either by soaking in sulphuric acid (98%) for 40-120 minutes or by a cold stratification (4 - 5 months). The long cold pre-treatment, safe and environmental friendly, acts positively in softening tissues and enabling moisture absorption even if it is less effective than acid soaking in promoting germination.

If the whole fruits have been cold-stratified, it may be useful to wash them in running water for 1-2 days before sowing, in order to facilitate removal of fruits' remaining tissues. However, it is more practical to utilise seeds already separated from the fruit.
It is possible that mechanical scarification, carried out before the cold stratification, will allow reduction of the subsequent cold treatment, as is the case with other species of *Rhamnaceae*.
Another technique envisages spring sowing using seed stratified in the open (stratification pits) since December.
No pre-treatment of seeds is performed in autumn sowings.
After dormancy has been removed, alternating temperatures of 25°C (8 hours with light) and 20°C (16 hours in the dark) seem to stimulate germination.

3.2.65. Phillyrea angustifolia L. (narrow leaf phillyrea) - *(Oleaceae)*
Average germination: ?
Number of seeds per kg: 112,000
Fully ripe fruits must be collected in December, before they fall. After being extracted from the fruit and separated from the pulp, the seed can be either stored or treated. The seeds can be stored for a few days without any special measures being taken, or for 2-3 months in a refrigerator, mixed with sand.
Before sowing, the seeds must be scarified mechanically or chemically (by immersion in concentrated sulphuric acid for 30 minutes, followed by thorough washing).
Sow immediately after collection or in the following spring.
Vegetative propagation is possible.

3.2.66. Phillyrea latifolia L. (tree phillyrea) - *(Oleaceae)*
See *P. angustifolia*

3.2.67. Pistacia lentiscus L. (lentisk, mastic-tree) - *(Anacardiaceae)*
Average germination: very variable, 40-80%
Number of seeds per kg: 30,000-85,000.
The seeds are rich in oily substances, therefore the quality of the seed, including viability, could be lost in a comparatively short space of time. In actual fact, there have been no thorough studies of the conditions required for good and lengthy storage of the seeds. It is advisable to remove the pulp immediately after collection, completing the operation by washing, which enables the floating (empty) seeds to be removed.
In the genus *Pistacia*, the epicarp may inhibit germination, while the endocarp may reduce the rate of imbibition. In the case of *P. lentiscus*, the endocarp actually proves to be a barrier, since it slows down the absorption of water and thus the germination process. In any case, the obstacle may be overcome by mechanical scarification. Alternatively, cold stratification may be employed, which acts by attacking the integrity of the seedcoats rather than by removing any physiological dormancy.
Sowing is usually done in autumn, immediately after collection, without any pre-treatment to seeds. Immersion of the seeds in water for 2-3 hours before sowing is advisable.
For spring sowing either scarified seed or cold stratified (2-3 weeks) seed is employed.
Under natural conditions, seed is bird-dispersed. Colonisation of an area is also favoured by the presence of trees and shrubs which, on the one hand, allows birds to perch and, on the other, creates a favourable microenvironment during the first stages of the seedlings development.
Studies have recently been carried out on the variability of some genetic characters in wild populations of lentisk in Sardinia. Marked differences have been pointed out among the ecotypes with respect to the extent of fruiting, the percentage of aborted ovaries, the viability of seeds and the speed of germination. A positive correlation has been found, also applicable to most of the species, between good seed crops and high germinability of seeds.
Among Mediterranean species, the lentisk is considered very important indeed because of its widespread distribution, its great ecophysiological variability and its highly-developed ability to adapt, survive and protect the soil. It is used as a rootstock for *Pistacia vera.*

Figure 17. Fruits of *Pistacia lentiscus* (L. Mezzalana)

Figure 18. Germination of *Pistacia lentiscus*, note the dark colour of the roots (L. Mezzalana)

3.2.68. Pistacia terebinthus L. (terebinth) - *(Anacardiaceae)*
Average germination:?
Number of seeds per kg: 17,000
Good seed crops are not so frequent: in many cases a high number of empty seeds are produced.
Autumn sowing, without any pre-treatment of seeds, or spring sowing using cold stratified seeds for 12 weeks.
Terebinth is usually propagated by seed to prepare rootstocks for *Pistacia vera.*
See *P. lentiscus.*

3.2.69. Platanus orientalis L. (oriental plane-tree) - *(Platanaceae)*
Average germination: generally low (30-40%)
Number of seeds per kg: 200,000-300,000
After having been air-dried until the moisture content has been reduced to 7-10%, the seed may be stored for several years if it is placed in sealed containers at a low temperature (+5° to +7°C).
Sowing is done immediately after collection (the end of winter) without any pre-treatment, or in spring using seed cold-stratified for 6-8 weeks. It is advisable to cover the seeds with a very thin layer of soil and protect them from fungi and from birds.

3.2.70. Populus spp. (poplar) - *(Salicaceae)*
Propagation is carried out almost exclusively by vegetative means.
If wishing to to propagate by seed, the fruit is collected if possible at the same time as it ripens. If the fruits are collected too soon, the seeds cannot achieve ripeness. On the other hand, wind dispersal (anemochory) occurs immediately after the fruits have ripened, thus there is a considerable risk of losing the best material.
Under natural conditions, the seeds have a very short life span (2-4 weeks) which, however, varies according to the species and the particular environmental conditions. The viability may be, however, maintained for comparatively long periods (several years) if the seed is stored at low temperatures (between –40° and +5°C) in small airtight containers after it has been carefully dried, gradually taking the moisture content down to 4-8%, by means of a slight current of air (+20°C for 2-5 days). In some cases the use of vacuum containers has improved these results. Using these techniques, a germination of 50-70% has been recorded for *P. deltoides, P. tremula, and P. grandidentata,* even after the seeds have been stored for 2-3 years. In the same way, a 97% germinability has been observed in *P. tremuloides* after 1 year in storage. On the other hand, seeds of *P. maximowiczii* that have not been dried have preserved their viability practically unchanged for 10 months at temperatures between minus 17°C and +3°C with 30% relative humidity.
Seeds of *P. nigra*, placed in small airtight phials (2 cm^3), under a partial vacuum, have kept 40% of their original germinability for 5 years; conditions for storage involved a seed moi-

sture content of about 8% and a temperature of between –15° and +4°C. By lowering the moisture content to 7% it was possible to maintain more than 80% of the initial germinability in this species.
Poplar seeds stored for comparatively long periods may be subject to damage when they are set to germinate, owing to a too rapid soaking. Therefore, before sowing they should be rehydrated gradually.
Under favourable conditions, germination occurs rapidly. If the seed is fresh the epicotyl emerges from the seedcoat after only 12 hours.
Even if they appear to be normal, poplar seeds produce variable percentages of abnormal seedlings.

3.2.71. Populus alba L. (white poplar) - *(Salicaceae)*
Average germination: ?
Number of seeds per kg: 1,600,000-1,800,000
See *Populus* spp.

3.2.72. Populus nigra L. (black poplar) - *(Salicaceae)*
Average germination: ?
Number of seeds per kg: 1,000,000-1,100,000
See *Populus* spp.

3.2.73. Prunus spp. - *(Rosaceae)*
The seeds belonging to this genus (there are about 200 species in the temperate-cold climates) often show endogenous dormancy and need a period of afterripening in moist but well-aired environments. The toughness of the endocarp proves a further hindrance to germination. Pre-treatments, usually consisting of a combination of warm and cold stratification are not always effective and vary according to species and provenances.
Immediately after collection of the fruits, which must be well ripened, it is advisable to remove the pulp, particularly to avoid moulds and plundering by birds and rodents. The seed intended for storage is kept at a moisture content of between 6 and 15%, usually between 9 and 10%, and arranged in airtight containers at temperatures varying between –3° and –1°C.
After dormancy has been removed, germination is favoured by marked daily alternating temperatures (warm by day, cold by night). Under natural conditions these correspond to late winter-early spring. Constant temperatures of +20°C induce secondary dormancy in non-dormant seeds, therefore late sowings, when the soil temperature is high, are to be avoided.
Vegetative propagation of ornamental and edible species is very widespread.

3.2.74. Prunus spinosa L. (blackthorn, sloe) - *(Rosaceae)*
Average germination: 80-90%
Number of seeds per kg: 4,400-6,000
Sowing in late winter-early spring uses seed warm stratified for 2-4 weeks and subsequently cold stratified for 4-18 weeks.
Constant temperatures of +20°C induce secondary dormancy in non-dormant seeds, therefore late sowings, when the soil temperature is high, are to be avoided.
See *Prunus* spp.

Figure 19. Seeds of *Prunus spinosa* (L. Mezzalana)

3.2.75. Punica granatum L. (pomegranate) - *(Punicaceae)*
Average germination: ?
Number of seeds per kg: 40,000
Autumn sowing, without any seed pre-treatment, or spring sowing using cold stratified seeds for 4-8 weeks.

3.2.76. Pyrus spp. (pear) - *(Rosaceae)*
Immediately after collecting the fruits, which must be fully ripe, it is advisable to remove the pulp, particularly so as to avoid moulds and plundering by birds and rodents. Seed intended for storage should be kept at a moisture content between 6 and 15%, usually between 9 and 10%, and arranged in airtight containers at temperatures varying between –3° and –1°C.
Sowing is performed immediately after collection, without any seed pre-treatment, or in late winter-early spring, using seed warm stratified for 2-4 weeks and cold stratified for 12-16 weeks.
After dormancy has been removed, germination is favoured by marked daily alternating temperatures (warm by day, cold by night). Under natural conditions these correspond to late winter-early spring. Constant temperatures of +20°C induce secondary dormancy in non-dormant seeds, therefore late sowings, when the soil temperature is high, are to be avoided.

3.2.77. Quercus spp. (oak) - *(Fagaceae)*
Growing interest in the management of woods for the production of acorns destined either for nursery production or for animal food has been noted. In the latter context, it is worth remembering that more than 200 animal species feed on acorns.
The genetic resources represented by the Mediterranean oaks, their great variability and their key role in ecology make the Mediterranean area an important one as regards biodiversity. The attention paid in the last few years to the cork oak, *Quercus suber*, has also been extended to other species, such as *Q. ilex,* and *Q. coccifera,* closely connected to each other and between which natural cross-breeding is possible. Outside the distribution area of *Q. suber*, especially in the eastern Mediterranean areas, the Mediterranean oaks often grow in isolated small populations. It cannot be said that they are threatened, but the innumerable obstacles placed in the way of their natural propagation, such as fragmentation of the territory and lack of animals that favour dispersal of the acorns, create difficulties for the maintenance of genetic variability.
Generally speaking, it is considered that the morphology and manner of growth of seedlings belonging to the genus *Quercus* show evolutionary responses to both the habitat and size of the seed. For example, wild species in a xerophytic environment generally prove to have comparatively small seedlings.
Oak flowering and fruiting are conditioned by the climate, the length of the reproductive cycle, the presence of insects and predators, the age and size of the tree, the position of flowers and the individual genetic capacity for the production of acorns. The longer the reproductive

Figure 20. Container for storing acorns, note the perforated tube that ensures gas exchange (L. Mezzalana)

Figure 21. Perforated plastic boxes containing naked acorns (previously subjected to thermoterapy) are placed inside larger containers for storage (C. Muller, INRA)

cycle of a species (it lasts for one year in *Q. ilex*, for two in both *Q. coccifera* and *Q. suber*), the more likely the danger of problems arising. Even fruiting is irregular in the oak species: large seed crops, exceeding 600,000 acorns/ha, occur every 2-5 years, according to the site and species, but the interval may increase owing to a number of factors, among them atmospheric pollution.
In areas where there is no danger of frost, sowing is done in autumn immediately after collection; otherwise, sowing takes place in spring using acorns stratified during the winter, usually in the open (stratification pits), but also in temperature regulated environments (between +1° and +5°C) (using pregerminated acorns if necessary). Cold stratification is of no use for removing dormancy (considered negligible or non existent in Mediterranean oak species), but is used above all to delay germination until the following spring. Autumn sown seed has to be protected from rodents and mulched in cold regions. The stratification medium (mixed with the acorns) must be checked periodically, particularly at the end of winter, to interrupt the pre-treatment before the tap-root has grown too long. To sow pregerminated acorns, the optimal length of the root is 0.5-5 cm, but seeds with longer tap-roots can be sown; when they are placed in the seed beds or in the containers these roots may be cut down to 3 cm without this having any negative effect on survival. The presence of insect larvae does not compromise germination, always provided that the embryo has not been damaged.
Acorns are recalcitrant, i.e., the loss of moisture has a negative effect on their viability. From collection up until sowing, the acorns' moisture content should not fall below 40%. The ideal moisture content is between 42 and 48%, but it varies according to the species. The seeds of *Q. pedunculata* and *Q. rubra* are very sensitive to dehydration. As regards *Q. rubra,* viability is definitively lost when the moisture content remains below 25%.
To encourage the normal conformation of the root system and the aerial part of the plant, acorns are placed in their natural position (horizontal) for cold stratification as well as for sowing.
It is possible to store acorns for 3-4 years in environments at temperatures between -3° and -1°C (at +1°C the seeds are able to germinate, the radicles of *Q. petraea* can develop even at -1°C) where excess of carbon dioxide can be removed. Acorns are mixed with dry (but not dehydrated) peat and arranged in 30-60 litre containers that permit gas exchange, usually ensured by perforated tubes (10 cm diameter and as high as the container) placed vertically in the centre. Each container is covered with a sheet of paper (porous but strong) or perforated cardboard, on which the lid of the container is put. In some European seed processing plants the acorns are subjected to thermotherapy (soaking in water at +41°C for 2 or 3 hours) to attack the fungus *Ciboria batschiana.* After a superficial drying (returning moisture content to about 45%) they are treated with fungicides (methylthiophanate, benomyl or iprodione) and then stored, without being mixed with any substrate, in perforated plastic boxes with a 30-50 litre capacity. Once they have been partially filled, these boxes are placed inside large containers (300-400 kg) which, in their turn, are piled up, allowing, however, a good oxygen/carbon dioxide ratio.
Before sowing the acorns stored in this way, it is advisable to soak them in water to restore the complete imbibition level and to easily separate non-viable seeds and various impurities. The method of separation by floating works quite well in the case of insect larvae infestation. The response of the various species to a 3-4 years storage is not consistent. In the case of *Q. pubescens,* for example, less satisfactory results are achieved. In some cases, particularly if storage conditions have not been optimal, a reduction of the vigour of seedlings has been observed.
The quality of the acorn affects both the total number of the future seedling's roots and also the number of permanent secondary roots.
Storage of recalcitrant seeds is nowadays considered one of the most difficult challenges in the field of forest nurseries and in the management of genetic resources.
The storage of acorns of Mediterranean oaks has not been sufficiently studied or practised; however, the methods described above may be applied, taking into account the differences between species. Some steps to be taken in research aimed at solving this problem are suggested. First of all, it is necessary to identify the moisture content corresponding to the complete imbibition of the acorns of every species; secondly, medium-term conservation of acorns

(3-4 years) should be carried out in structures similar to those described above, using acorns with a water level 5% less than that of maximum imbibition.

3.2.78. Quercus coccifera L. (kermes oak) - *(Fagaceae)*
Average germination: 60-80%
Number of seeds per kg: 200-500 (340)
See *Quercus* spp.

3.2.79. Quercus ilex L. (evergreen oak, holly oak) - *(Fagaceae)*
Average germination: 80-90%
Number of seeds per kg: 250-550 (400)
See *Quercus* spp.

3.2.80. Quercus macrolepis Kotschy L. (valonia oak) - *(Fagaceae)*
Average germination: 70-90%
Number of seeds per kg: 55-90 (60-70)
See *Quercus* spp.

3.2.81. Quercus pedunculata Ehrh. *(=Q. robur* L. subsp. *robur)* (pedunculate oak) - *(Fagaceae)*
Average germination: 75%
Number of seeds per kg: 250
See *Quercus* spp.

3.2.82. Quercus pubescens Willd. (pubescent oak) - *(Fagaceae)*
Average germination: 80-90%
Number of seeds per kg: 250-400
See *Quercus* spp.

3.2.83. Quercus suber L. (cork oak) - *(Fagaceae)*
Average germination: 70-90%
Number of seeds per kg: 200-300
See *Quercus* spp.

3.2.84. Quercus trojana Webb. (Macedonian oak) - *(Fagaceae)*
Average germination: 70-90%
Number of seeds per kg: 70-260
See *Quercus* spp.

3.2.85. Rhamnus alaternus L. (Italian buckthorn) - *(Rhamnaceae)*
Average germination: 50-70%
Number of seeds per kg: 20,000-50,000
After collection in autumn, the pulp must be removed from the ripe fruits in order to recover the seeds which, once they have been dried, may be stored in airtight containers for several years at low temperatures. Autumn sowing, without any pre-treatment to seeds, or spring sowing using seeds that have been cold stratified for 4-12 weeks. Scarification (mechanical or chemical) performed before cold stratification may improve germination.
Vegetative propagation for many species of the genus *Rhamnus* is possible by means of semi-hardwood cuttings collected in summer.

3.2.86. Rhus spp. (sumac) - *(Anacardiaceae)*
The presence of *R. typhina,* naturalised in Italy, and of *R. coriaria* is frequently met within the Mediterranean area.
Species of the genus *Rhus* often produce a considerable number of empty seeds.
The endocarp of *Rhus* drupes, which always have only one seed, is very hard and impermeable to water. It acts as a protective layer for the embryo and is the main cause of its dor-

mancy, the degree of which varies greatly between one species and another and, within the same species, between one seed lot and another. The endocarp's impermeability is such that if the seeds of *R. aromatica, R. copallina, R. glabra* and *R. typhina* are kept on a moist substrate for 4 weeks, only 0-14% of the total number of seeds prove to be imbibed. However, other species such as *R. trilobata, R. microphylla* and *R. virens* have less tough endocarps and they imbibe more easily. Mechanical scarification, a high dry temperature in an oven (+100°/+120°C), immersion in boiling water or in concentrated sulphuric acid are treatments that can render the endocarps more permeable. With regard to *R. glabra* and *R. typhina,* it is sufficient to immerse the seeds in boiling water to make them permeable, while other species (*R. aromatica, R. trilobata* and *R. virens)* need a more drastic treatment to scarify the seeds (immersion in sulphuric acid for 1 hour or more).
Rhus spp. seeds can be stored well for several years, at least 4.
With regard to seeds of the genus *Rhus* growing wild in areas where there are frequent fires, these seem to play an important role in attacking the endocarp. However, the appearance of seedlings after the fire has passed could be the result not so much of the high temperatures that might scarify the seed, as of an increased survival capacity due to the elimination of possible competitive factors (foliage, other plants, etc.).
Since a high temperature in absence of moisture is unable to remove dormancy by itself, it is possible to theorise that under natural conditions it is a combination of high temperatures resulting from the fire and moisture in the ground that encourages germination.
Germination of seeds of *R. coriaria*, which usually follows fires, is conditioned by the high temperatures as well as the ethylene released from the ash. However ash can in some cases inhibit germination processes by means of a high pH and a low water potential. The mode of dispersal (birds) and the ecophysiological conditions in which *R. coriaria* grows implies that, in natural conditions, germination takes place mostly under burnt crowns of conifers in fertile soils and in absence of competition.
Vegetative propagation of ornamental species is widespread.

3.2.87. Rhus typhina L. (staghorn sumac) - *(Anacardiaceae)*
Average germination: 40-90%
Number of seeds per kg:. 108,000-150,000 (118,000)
The seeds are dispersed by many species of birds and mammals, thus making the colonisation of new areas possible.
The seeds of *R. typhina* keep their viability for at least 5 years.
Empty seeds have different forms and colours from viable ones. This characteristic makes it possible to select viable seeds by hand.
Germination is hindered by the tough and impermeable endocarp whose integrity may be breached by mechanical scarification, immersion in hot water (some authors advise immersion in boiling water for 30-60 seconds) or in sulphuric acid (1-3 hours). The former method seems to be the most effective, while the duration of chemical scarification may vary according to the provenance and is dangerous. Cold stratification after scarification can favour germination.
After scarification sowing may be performed, preferably at a constant temperature (+20°C) or alternating (warm-cold). On the contrary, a higher constant temperature (+35°C) may hinder germination.
After dormancy has been removed, germination is favoured by darkness.
To summarise, autumn sowing is done with scarified seed, while spring sowing is performed with scarified seed, preferably if it has also been cold stratified (scarification + cold stratification).
Vegetative propagation by means of cuttings and root suckers is possible.

3.2.88. Rosa spp. - *(Rosaceae)*
Some species of the genus, such as *R. sempervirens*, are widespread in the coastal strip of the Mediterranean basin.
In the genus *Rosa*, the seeds' dormancy, due to the toughness of the pericarp, the underdevelopment of the embryo and the presence of various kinds of inhibitor, poses a considerable problem for the production of seedlings. Such complex dormancies generally need warm stra-

tification (8-20 weeks) followed by cold stratification (8-20). In a few species only cold stratification may suffice.
After the fruits (hips) have been extracted, the dried achenes may be treated with concentrated sulphuric acid to corrode the pericarp. They must then be washed to remove the acid residue and then warm stratified (+20°C) for about 8-12 weeks and cold stratified for 8-20 weeks. Instead of using corrosive substances, warm stratification may be prolonged (15-24 weeks), leaving the cold stratification unaltered.
Compost starters are currently available on the market; if mixed with stratification medium, they accelerate decomposition of the seedcoats, making it possible to reduce the period of warm stratification. The level of compost starters used may vary according to the species.
Sowing of non-dormant (pre-treated) seeds is done in periods of the year (late winter-early spring) with marked temperature fluctuations (cold nights/warm days). Late spring sowing may cause secondary dormancy in the seed if the ground temperature is too high.
Vegetative propagation of the ornamental species is very widespread.

3.2.89. Rosa canina L. (dog rose) - *(Rosaceae)*
Average germination: 40-50%
Number of seeds per kg: 50,000-100,000 (60,000)
Sow immediately after collection, without any pre-treatment of the seeds, or in late winter-early spring using seeds warm stratified for 8-24 weeks and then cold stratified for a further period of 8-24. The addition of substances normally used as compost starters to the stratification medium shortens the length of the treatment, because they probably attack the seedcoats making them more sensitive to the treatment itself.
The length of the warm-moist + cold-moist pre-treatment varies greatly according to the provenance of the species and it is therefore good practice to check the stratified seeds towards the end of the cold stratification. *R. canina* seeds germinate easily at low temperatures, while high temperatures bring on secondary dormancy. Sowing of non-dormant (pre-treated) seeds is done in periods of the year (late winter-early spring) with marked temperature fluctuations (cold nights/warm days). Late spring sowing may cause secondary dormancy in the seed if the ground temperature is too high. See *Rosa* spp.

3.2.90. Rosmarinus officinalis L. (Rosemary) - *(Labiatae)*
Average germination: 30-50%
Number of seeds per kg: 975,000
Under natural conditions and in the absence of fire, the species rarely resorts to propagation by seed. After fires, which completely burn the aerial part of the plant, rosemary makes use exclusively of sexual reproduction to rapidly colonise the areas previously occupied. However, such a habit does not seem to be linked to the occurrence of fire. In fact, the seed has no need of temperature shocks in order to germinate, as is the case, for example, with the genus *Cistus*, but it can bear comparatively high temperatures (+40°/+60°C for 24 hours) without this having a negative effect on its ability to germinate. Temperatures of about +100°C for 15 minutes, on the contrary, cause severe damage to the germinability but do not destroy all the seeds. This tolerance is to be interpreted as a feature of pioneering plants, the seeds of which can be exposed to torrid conditions in soils denuded by fire or usually lacking plant cover.
R. officinalis' strategy of adaptation to the Me-


Figure 22. Flowering of *Rosmarinus officinalis* (C. Piccini, APAT)

diterranean climate envisages a flowering and a subsequent dispersal over a very lengthy period. This leads to the formation of large soil seed banks, thus allowing the species to await the most favourable moment for germination. During fires, the temperature rarely exceeds +110°C beyond the first centimetre of earth and therefore the seed banks enable the burnt soil to be repopulated.
Collection and processing of the seed is quite simple. Cool, dry environments are used for storage (+3°/+5°C).
There would be no reason to pre-treat the seed, but cold stratification for 30-60 days favours the speed and uniformity of germination. Temperatures around +20°C and absence of light are the optimal conditions for a rapid emergence. The seedlings are rather delicate and must be protected from intense sun during the first stages of their development.
Spring sowing, using seeds that may have undergone cold stratification for a short period.
Vegetative propagation is widespread.

3.2.91. Rubus spp. (raspberry, blackberry bush) - *(Rosaceae)*
This is a genus with a wide-ranging occurrence and numerous species. In the case of *Rosaceae,* owing to the tough pericarp, the underdevelopment of the embryo and the presence of various kinds of inhibitor, dormancy of the seeds poses a considerable problem for the production of seedlings. Such complex dormancies are usually removed by warm stratification followed by cold stratification.
Sowing takes place in late winter-early spring, using seeds subjected to warm stratification for 2-3 months, followed by cold stratification for a further 2-3 months. Scarification (mechanical or chemical) of the seedcoats, performed before warm + cold stratification, could improve the completeness and rapidity of germination.
Germination is probably encouraged by marked fluctuations of temperature (e.g., +25°C by day and +5°C by night).
Vegetative propagation by means of cuttings and root suckers is possible in many species.

3.2.92. Ruscus aculeatus L. (butcher's broom) - *(Liliaceae)*
Average germination: ?
Number of seeds per kg: 2,000-5,000
Number of fruits per kg: 800
This is a dioecious plant, therefore only the females have an attractive appearance. The species is arousing interest at present because of the saponin contained in the rhizomes, for which a therapeutic effect is claimed for cardiovascular diseases.
After collection, usually in December, the whole berries may be stratified before spring sowing. Otherwise, the pulp may be removed from the fruits by maceration to obtain clean seeds (1 or 2 per berry) and to avoid the formation of mould. An average of 30 kg of seed is obtained from 100 kg of fresh fruits.
No data are available as to the conservability of the seeds, but it is believed that it is possible to maintain their viability for several years.
This species' seeds have a marked dormancy. Even today no methods are known that are really effective in rapidly stimulating their germination, but studies are in progress. Spring sowing, preceded by cold stratification (in the open in stratification pits or in controlled conditions), does not give satisfactory results since germination is only partial, slow and erratic.
The theory of a complex morpho-physiological type of dormancy would suggest a pre-treatment consisting of warm stratification for 4-8 weeks followed by cold stratification for 8-12 weeks, even for several cycles, with spring sowing.

3.2.93. Ruta chalepensis L. (rue) - *(Rutaceae)*
Average germination: ?
Number of seeds per kg: ?
Under natural conditions the plant reproduces easily by seed, even on highly degraded soils, provided that they are well exposed and sited in warm areas.
A short period of cold stratification (7-14 days) may make germination more rapid and uniform.

3.2.94. Salix spp. (willow) - *(Salicaceae)*
Seeds of the numerous species, about 300 (all dioecious), lose their viability a few days after dispersal. The seeds may be stored for up to 30 days if they are imbibed and placed in airtight containers in a refrigerated environment. On the other hand, if the moisture content is reduced to 7-8% and the temperature is taken to –20/0°C (preferably –20°C) the seed quality may be maintained for at least 44 months.
The seeds are very small, but vary considerably between one species and another (1,100,000 seeds per kg in *S. petiolaris,* 25,400,000 in *S. lasiandra*).
It is commonly propagated by vegetative means.
See *Populus* spp.

3.2.95. Salvia spp. - *(Labiatae)*
Under natural conditions, plants belonging to the genus *Salvia* are widespread in zones characterised by frequent seasonal fires. The seeds remain dormant until, after the fire has passed, optimal conditions for germination have been restored (e.g. increased quantities of wood ash). Such behaviour is very probably a form of adaptation to living in environments suffering frequent fires.
Salvia seeds, which may have deep dormancy, can show increased germination after a period of afterripening lasting 1-2 months after collection. Furthermore, removal of the structures covering the seeds (including seedcoats), cold stratification, and treatment with gibberellins (GA_3, from 10 to 1000 ppm) are effective methods for removing dormancy. The seeds of some species (*S. apiana)* respond positively to exposure to smoke. However, the most usual method for breaking dormancy is a short period of cold stratification at +4°/+5°C, which may vary from a few days to several weeks according to the species.
Should the seeds be non-dormant, they may be incubated for 16 hours at +20°C or, alternatively, at +30°C for 8 hours. Germination is favoured by alternating temperatures (+20°/+30°C) and by the presence of light. Darkness has an inhibiting effect.
The seeds of *Salvia* spp. usually maintain their viability for a long time.
Vegetative propagation is very widespread.

3.2.96. Smilax aspera L. (smilax, greenbrier) - *(Liliaceae)*
Average germination: usually low
Number of seeds per kg: ?
The seeds' dormancy is complex (probably linked to bird dispersal) and even today no effective pre-treatments for removing it are known. It is likely that the combination of warm stratification + cold stratification before sowing can improve the percentage of germination.
Fully ripened berries are collected at the end of summer and the pulp is removed immediately, sowing takes place immediately afterwards. Part of the germination occurs during the following spring while most seeds will germinate during the second and the third spring after dispersal.

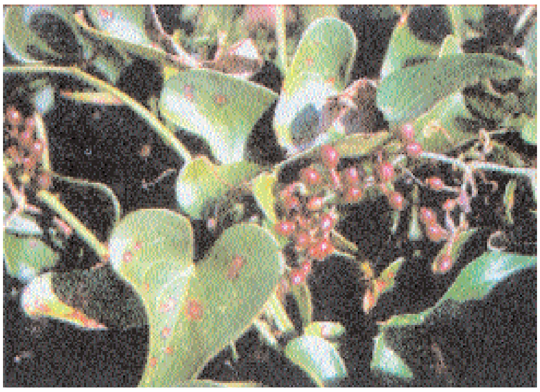
Figure 23. Fruits of *Smilax aspera* (L. Mezzalana)

3.2.97. Sorbus spp. (mountain ash, service tree) - *(Rosaceae)*
In order to store the seeds, it is necessary to lower the moisture content to around 9-10% and place them in airtight containers at a temperature of between –18° and +3°C. Under these conditions the quality is maintained for 2-3 years.
Sowing is done immediately after collection, without any pre-treatment to seeds, or in late winter-early spring, using seeds warm stratified for 2-4 weeks and cold stratified for 12-16 weeks. In many cases, only open air stratification (stratification pits) is performed from collection until sowing, or only cold stratification in a temperature-controlled environment for 8-16 weeks before sowing.
Sowing of non-dormant (pre-treated) seeds is done in periods of the year (late winter-early

spring) with marked temperature fluctuations (cold nights/warm days). Late spring sowing may cause secondary dormancy in the seed if the ground temperature is too high.

3.2.98. Sorbus domestica L. (service tree) - *(Rosaceae)*
Average germination: ?
Number of seeds per kg: 32,000
See *Sorbus* spp.

3.2.99. Sorbus torminalis (L) Crantz. (checker tree) - *(Rosaceae)*
Average germination: 70-80%
Number of seeds per kg: 28,000-56,000 (40,000-50,000)
See *Sorbus* spp.

3.2.100.Spartium junceum (Spanish broom, weaver broom) - *(Leguminosae)*
Average germination: ?
Number of seeds per kg: 67,000-100,000 (75,000-85,000)
Sown in spring, usually in a seedbed with subsequent transplanting.
Scarification of the seedcoats increases percentage and speed of germination.
See *Leguminosae.*

3.2.101.Staphylea pinnata L. (European bladdernut) - *(Staphyleaceae)*
Average germination: ?
Number of seeds per kg: ?
Sown immediately after collection, without any pre-treatment to seed, or in spring, using seed warm stratified for 12 weeks and cold stratified for 12 weeks

3.2.102.Tamarix spp. (tamarisk) - *(Tamaricaceae)*
Under natural conditions, the viability of the tiny seeds (*T. gallica* has up to 1,000,000 seeds per kg) is quickly lost. Sowing, without any pre-treatment, should follow collection, which occurs in spring-summer. The seed may be stored at a temperature of +3°/+4°C for 1-2 years, but a considerable loss of viability results.
Stored seed may be used for spring sowing in a seedbed with subsequent transplanting. Germination occurs rapidly, but early development of the seedlings is slow.
Vegetative propagation by means of cuttings taken in autumn-winter is widespread.

3.2.103.Thymus spp. *(thyme) - (Labiatae)*
Average germination:?
Number of seeds per kg:?
Spring sowing.
Germination is favoured by light and by alternating temperatures (+20°/+30°C).
Vegetative propagation is possible.

3.2.104.Ulex europaeus L. (common gorse) - *(Leguminosae)*
Average germination: 70-80%
Number of seeds per kg: 145,000-269,000 (156,000)
The tough impermeable seedcoats hinder germination.
Sow in spring using mechanically scarified seed.
See *Leguminosae.*

3.2.105.Ulmus spp. (elm) - *(Ulmaceae)*
Sown immediately after collection in early spring. After collection or natural dispersal the viability, which is very high to begin with, is quickly lost.
It is sometimes possible to maintain the viability of the seeds for several years if they are dried up to 10% and stored in airtight containers at +2°/+4°C.
After sowing it is essential to maintain the surface moisture of the ground. Under favourable climatic conditions, germination begins after a few days.

The selected varieties of elm may be propagated by hardwood cuttings taken during the period of vegetative rest, from one yearold branches or from suckers at the base of the trunk. Grafting may be employed in some cases (*U. glabra)* or layering (*U. minor).*

3.2.106.Viburnum spp. (viburnum) - *(Caprifoliaceae)*

The seeds, after being depulped, are cleaned and air-dried, and may then be stored in airtight containers at low temperatures for several years.

No completely effective methods of removing the complex dormancy shown by the seeds of this genus are known.

Warm stratification followed by cold stratification is advised for most of the species. The seeds undergoing stratification have to be checked frequently, because they germinate easily at low temperatures.

Sown in autumn, without pre-treating seeds, or in spring using pre-treated seed.

Many species sown in autumn without pretreatment germinate during the second spring.

Figure 24. Flowering *Viburnum tinus* (C. Piccini, APAT)

Many species of the genus *Viburnum* propagate by cuttings, generally taken in summer but in some cases even in spring (*V. tinus*).

3.2.107.Vitex agnus-castus L. (lilac chastetree, chaste tree*)* - *(Verbenaceae)*

Average germination: usually high

Number of seeds per kg: 74,500-130,000 (100,000)

Good seed crops occur almost every year, particularly in deep, moist soils along watercourses.

Between late summer and early autumn the fruits may be handpicked or recovered from ground sheets laid under the plants.

Seed yield from fruits, on a weight basis, is about 75%.

The seeds maintain their quality if they are stored at low temperatures (+3°C). They germinate easily without any pre-treatment if they are sown 'fresh' (immediately after collection, seed that has not been stored), otherwise they need cold stratification for 2 or 3 months.

Sown immediately after collection, without pre-treatment, or sown in spring using cold-stratified seeds.

Vegetative propagation is possible; sometimes it is easier by layering than by employing cuttings.

3.2.108.Vitis spp. (grape) - *(Vitaceae)*

The seeds play an entirely marginal role in propagation, even with wild grape plants, they are used only in breeding programmes to produce new cultivars. In natural conditions vegetative propagation by layering is most frequently seen.

The seeds of *V. vinifera* germinate quite well if they are sown in spring after cold stratification for 4-12 weeks; on the contrary, 17-30 weeks of cold stratification are advised for *V. labrusca*. Gibberellins may shorten the length of cold stratification, therefore in genebanks the following pre-treatment is applied for the genus *Vitis:* immersion in oxygenated water (0.5 M) for 24 hours, followed by immersion in gibberellins (GA_3, 1000 ppm) for a further 24 hours and, finally, cold stratification for 3 weeks. Stratification can be performed with 'naked' seeds or mixed with a stratification medium; in either case, seeds with all the pulp carefully removed must be used, so as to prevent moulds.

Germination may be hindered by the toughness of the seedcoats in some commercial varieties.

After pre-treatment, alternating temperatures (16 hours at +20°C in darkness and 8 hours at +30°C in the light) seem to encourage germination, but good results have also been noted at a constant +25°C.

4. Recommended seed treatments before sowing

Notes

(CD) = refers to species with a '**c**omplex **d**ormancy'. In the table **(CD)** has been used for those species that need long pre-treatments or combination of pre-treatments. It has also been used to indicate supposed complex dormancies, *i.e.* dormancies that cannot be removed by usual pre-treatments employed in the nursery.
For a number of species showing complex dormancy, autumn sow is suggested. This is because natural conditions are able to remove dormancy, in a period that can be rather long, and in some cases represent the only possibility to obtain seedlings.

(GC) = refers to seeds of species which are able to germinate at rather low temperatures therefore, for these species, it is advisable to check the stratification medium frequently towards the end of cold stratification.

(SD) = refers to species which non-dormant seeds (seeds that have removed dormancy) can be induced in **s**econdary **d**ormancy if subjected to high temperatures (about 20°C). In these species germination of non-dormant seeds is favoured by marked daily alternating temperatures; under natural conditions these correspond to late winter-early spring (warm by day, cold by night).

Figure 25. Germination of seeds of *Prunus spinosa* after a warm + cold stratification (L. Mezzalana)

GYMNOSPERMAE

Species	Sowing period and general remarks	Pre-treatment		
		scarification	warm stratification (weeks)	cold scarification (weeks)
Cupressus sempervirens	Spring sow in a seed bed, possibly with cold stratified seeds			0-4
Juniperus spp.	Autumn sow without pre-treatment in well-mulched nursery beds or late winter-early spring sow with pre-treated seed. See 3.1.2. *Juniperus* spp. **(CD)**			
Juniperus communis	Autumn sow without pre-treatment or late winter-early spring sow with pre-treated seed (in some cases warm stratification is not needed) **(CD)**		0-12	12-16
Juniperus oxycedrus subsp. *macrocarpa*	Autumn sow			
Juniperus phoenicea	Autumn sow without pre-treatment or late winter-early spring sow with pre-treated seed **(CD)**			4-12
Pinus brutia	Spring sow without pre-treatment (a short cold stratification may have a positive effect)			0-8
Pinus halepensis	Sow in spring or at summer-end			
Pinus pinaster	Sow in spring with or without pre-treatment (cold stratified seed may perform better) or at summer-end without pretreatment			0-4
Pinus pinea	Sow in spring or at summer-end			

ANGIOSPERMAE

Species	Sowing period and general remarks	Pre-treatment		
		scarification	warm stratification (weeks)	cold scarification (weeks)
Acer spp.	Autumn sow without pre-treatment or spring sow with pre-treated seed. See 3.2.1. *Acer* spp. **(GC)**			
Acer campestre	Autumn sow without pre-treatment or spring sow with pre-treated seed (warm stratification + cold stratification, in some cases a long cold stratification, only, can be enough) **(CD) (GC)**		0-8	12-24
Acer monspessulanum	Autumn sow without pre-treatment or spring sow with cold stratified seed **(CD) (GC)**			8-12
Acer opalus	Autumn sow without pre-treatment or spring sow with pre-treated seed **(GC)**		0-12	4-12
Alnus cordata	Sow by the end of February without pre-treatment or in spring with cold stratified seed (pre-treated with or without stratification medium)			4-6
Alnus glutinosa	*idem*			6-16
Amorpha fruticosa	Autumn sow without pre-treatment or spring sow with either scarified or cold stratified seed (scarification may substitute cold stratification)	mechanical or chemical		8-12
Anthyllis spp.	Spring sow with scarified seed			
Arbutus unedo	Autum sow without pre-treatment or spring sow with cold stratified seed (in some cases stratification is not performed)			0-8

(continued)

ANGIOSPERMAE				
Species	Sowing period and general remarks	Pre-treatment scarification	warm stratification (weeks)	cold scarification (weeks)
Artemisia spp.	Spring sow			
Asparagus acutifolius	Autumn or spring sow, in both cases with scarified seed	warm water for 12 hours		4-8
Asparagus officinalis	Spring sow with cold stratified seed			4-8
Atriplex spp.	See 3.2.12. *Atriplex* spp.			
Atriplex halimus	Sow in January-February without pre-treatment			
Berberis spp.	Autumn sow without pre-treatment or spring sow with cold stratified seed			6-13
Berberis vulgaris	*idem*			6-13
Calicotome spinosa	Spring sow with scarified seed. See 3.2.54. *Leguminosae*	warm water (40°C) for 15 minutes		
Capparis spinosa	See 3.2.17. *Capparis spinosa* L.			
Carpinus orientalis	Spring sow with pre-treated seed (warm stratification + cold stratification) **(CD) (GC)**		3-4	12-15
Celtis australis	Autumn sow without pre-treatment or spring sow with cold stratified seed **(GC)**			8-12
Centaurea cineraria	Spring sow without pre-treatment (a short cold stratification may have a positive effect)			
Ceratonia siliqua	Spring sow with scarified seed. See 3.2.21. *Ceratonia siliqua* L.	mechanical		
Cercis siliquastrum	Spring sow with scarified seed (sometimes cold stratification following scarification has a positive effect). See 3.2.54. *Leguminosae* and 3.2.22. *Cercis siliquastrum* L.	mechanical		0-12
Chamaerops humilis	Remove flesh from the drupes, soak seeds in water at 20°C for 1-2 days and sow in hot beds (+20°C / +25°C). In hot areas autumn sowing is practised after collection			
Cistus spp.	See 3.2.24. *Cistus* spp.			
Colutea arborescens	Spring sow with scarified seed. See 3.2.54. *Leguminosae*	mechanical		
Cornus mas	Autumn sow without pre-treatment (germination takes place during the second spring) or spring sow with warm + cold stratified seed. Scarification performed before warm + cold stratification may have a positive effect. **(CD)**		16	4-16
Cornus sanguinea	Autumn sow without pre-treatment or spring sow with warm + cold stratified seed. Scarification performed before warm + cold stratification may have a positive effect. In some cases warm scarification is not performed.		0-8	8-16
Coronilla spp.	Spring sow with scarified seed (sometimes cold stratification following scarification has a positive effect). See 3.2.54. *Leguminosae*	mechanical		
Cotinus coggygria	Spring sow with scarified + cold stratified seed **(CD)**	mechanical or chemical (sulphuric acid 20-80 minutes)		8-16

(continued)

ANGIOSPERMAE				
		Pre-treatment		
Species	Sowing period and general remarks	scarification	warm stratification (weeks)	cold scarification (weeks)
Crataegus spp.	Autumn sow without pre-treatment (most seeds will germinate during the second spring) or winter-end/spring-start sow with warm + cold stratified seed. Scarification performed before warm + cold stratification may have a positive effect. **(CD)**		4-16	12-36
Cytisus scoparius	Spring sow with scarified seed	mechanical or chemical (sulphuric acid 15-30 minutes)		
Daphne gnidium	Autumn sow without pre-treatment or spring sow with warm + cold stratified seed.		8-12	12-14
Daphne mezerum	*idem*		8-12	12-14
Daphne sericea	*idem*		8-12	12-14
Eleagnus angustifolia	Autumn sow without pre-treatment or winter-end/spring-start sow with pre-treated seed (warm stratification + cold stratification; in some cases cold stratification, only, can be enough). Alternatively, spring sow can be performed using seeds that have been soaked in running water (+15°C) for 6 days and subsequently cold stratified for 4 weeks **(SD)**		0-4	4-12
Erica spp.	See 3.2.38. *Erica* spp.			
Euonymus europaeus	Autumn sow without pre-treatment or winter-end/spring-start sow with pre-treated seed (warm stratification + cold stratification)		8-12	8-16
Euphorbia dendroides	Sow either at summer-end/autumn-start or is spring without pre-treatment			
Ficus carica	See 3.2.41. *Ficus carica* L.			
Fraxinus angustifolia	Autumn sow without pre-treatment or winter-end/spring-start sow with pre-treated seed (4 weeks warm stratification + 4-8 weeks cold stratification, alternatively 16 weeks cold stratification) **(CD) (GC) (SD)**		0-4	4-16
Fraxinus ornus	Autumn sow without pre-treatment or winter-end/spring-start sow with pre-treated seed (warm stratification + cold stratification) **(CD) (GC) (SD)**		2-8	8-15
Genista spp.	Spring sow with scarified seed. See 3.2.45. *Genista* spp. and 3.2.54. *Leguminosae*	mechanical or chemical (sulphuric acid 30 minutes)		
Glycyrrhiza glabra	Spring sow with scarified seed	mechanical		
Helichrysum spp.	Spring sow			
Hippophaë rhamnoides	Autumn sow without pre-treatment or spring sow with cold stratified seed			4-12
Laurus nobilis	Seed desiccation causes loss of viability. Autumn sow without pre-treatment or spring sow with cold stratified seed (usually in the open)			6-12
Lavandula spica	Spring sow without pre-treatment			

(continued)

ANGIOSPERMAE				
			Pre-treatment	
Species	Sowing period and general remarks	scarification	warm stratification (weeks)	cold scarification (weeks)
Lavandula stoechas	Autumn sow without pre-treatment			
Lavatera arborea	Spring sow with scarified seed (sometimes a short period of cold stratification following scarification has a positive effect on germination).	mechanical or chemical		0-8
Lembotropis nigricans	Spring sow with scarified seed. See 3.2.54. *Leguminosae*	mechanical or physical		
Ligustrum spp.	Autumn sow without pre-treatment or spring sow with cold stratified seed			4-12
Lonicera spp.	See 3.2.57. *Lonicera* spp.			
Myrtus communis	Late autumn sow without pre-treatment or spring sow with cold stratified seed			3-6
Nerium oleander	Spring sow, possibly with seed subjected to a short cold stratification			0-1
Olea europaea	See 3.2.60. *Olea europaea* L. subsp. *sativa* Offm. et Link			
Opuntia ficus-indica	See 3.2.61. *Opuntia ficus-indica* (L.) Miller			
Ostrya carpinifolia	Winter-end/spring-start sow with pre-treated seed (warm stratification + cold stratification) **(CD) (GC) (SD)**		4-8	16-23
Osyris alba	Autumn sow in seedbeds, immediately after collection, without pre-treatment			
Paliurus spina-christi	Autumn sow without pre-treatment or spring sow with cold stratified seed. See 3.2.64. *Paliurus spina-christi* Miller			10-20
Phillyrea spp.	Autumn or spring sow, in both cases scarified seed is recommended	mechanical or chemical (sulphuric acid 30 minutes)		
Pistacia lentiscus	Autumn sow without pre-treatment or spring sow with 2-3 weeks cold stratified seed. Alternatively, spring sow with mechanically scarified seed. See 3.2.67. *Pistacia lentiscus* L.			
Pistacia terebinthus	Autumn sow without pre-treatment or spring sow with cold stratified seed.			12
Platanus orientalis	Sow immediately after collection (winter) without pre-treatment or spring sow with cold stratified seed			6-8
Populus spp.	Sow immediately after collection (spring). See 3.2.70. *Populus* spp.			
Prunus spinosa	Winter-end/spring-start sow with warm + cold stratified seed. **(CD) (SD)**		2-4	4-18
Punica granatum	Autumn sow without pre-treatment or spring sow with cold stratified seed.			4-8
Pyrus spp.	Autumn sow without pre-treatment or winter-end/spring-start sow with warm + cold stratified seed. **(CD) (SD)**		2-4	12-16
Quercus spp.	Seed desiccation causes loss of viability. Autumn sow without pre-treatment or spring sow with cold stratified seed (usually in the open). See 3.2.77. *Quercus* spp.			

(continued)

ANGIOSPERMAE				
		Pre-treatment		
Species	Sowing period and general remarks	scarification	warm stratification (weeks)	cold scarification (weeks)
Rhamnus alaternus	Autumn sow without pre-treatment or spring sow with cold stratified seed. See 3.2.85. *Rhamnus alaternus* L. **(CD)**			4-12
Rhus typhina	Autumn or spring sow, in both cases scarified seed is recommended. Sometimes cold stratification following scarification has a positive effect. See 3.2.86. *Rhus* spp. and 3.2.87. *Rhus typhina* L.	Mechanical, physical or chemical (sulphuric acid 1-3 hours)		
Rosa canina	Winter-end/spring-start sow with warm + cold stratified seed. Compost starters mixed to the stratification can reduce the period of warm stratification. See 3.2.88. *Rosa* spp. **(CD) (GC) (SD)**		8-24	8-24
Rosmarinus officinalis	Spring sow, possibly with seed subjected to a short cold stratification			0-8
Rubus spp.	Winter-end/spring-start sow with warm + cold stratified seed. Mechanical or chemical scarification performed before warm + cold stratification may have a positive effect on germination. **(CD) (SD)**		8-12	8-12
Ruscus aculeatus	Seeds have a marked dormancy. No methods are known that are really effective in promoting germination. Autumn sow without pre-treatment (germination takes place during the second and third spring) or spring sow with warm + cold stratified seed, even for several cycles **(CD)**		4-8	8-12
Ruta chalepensis	Spring sow, possibly with seed subjected to a short cold stratification			0-2
Salix spp.	Sow immediately after collection (spring). See 3.2.94. *Salix* spp.			
Salvia spp.	Spring sow, a number of *Salvia* species need cold stratification. See 3.2.95. *Salvia* spp.			
Smilax aspera	No methods are known that are really effective in promoting germination. Autumn sow without pre-treatment (germination takes place during the second and third spring). See 3.2.96. *Smilax aspera* L. **(CD)**			
Sorbus domestica	Autumn sow, as soon as possible after collection, without pre-treatment or late winter-early spring sow with warm + cold stratified seed, in some cases only cold stratification is performed **(CD) (SD)**		0-4	12-16
Sorbus torminalis	*idem*		0-4	12-16
Spartium junceum	Spring sow with scarified seed. See 3.2.54. *Leguminosae*	mechanical		
Staphylea pinnata	Autumn sow, as soon as possible after collection, without pre-treatment or spring sow with warm + cold stratified seed **(CD)**		12	12
Tamarix spp.	Spring sow, as soon as possible after collection (spring), without pre-treatment			

(continued)

ANGIOSPERMAE				
Species	Sowing period and general remarks	Pre-treatment scarification	warm stratification (weeks)	cold scarification (weeks)
Thymus spp.	Spring sow			
Ulex europaeus	Spring sow with scarified seed. See 3.2.54. *Leguminosae*	mechanical *or* physical		
Ulmus spp.	Spring sow, as soon as possible after collection (spring), without pre-treatment			
Viburnum spp.	Autumn sow without pre-treatment or late winter-early spring sow with warm + cold stratified seed. See 3.2.106. *Viburnum* spp. **(CD) (GC)**			
Vitex agnus-castus	Autumn sow, as soon as possible after collection, without pre-treatment or spring sow with cold stratified seed			8-12
Vitis vinifera	Autumn sow without pre-treatment or spring sow with cold stratified seed			4-12

Figure 26. Germination of *Ulmus minor* seeds a few days after sowing without pre-treatment (L. Mezzalana)

5. Suggested reading

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7. Suggested WEB sites

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British Columbia Ministry of Forests: http://www.gov.bc.ca/for/

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Canadian Forest Service, National Tree Seed Centre: http://www.atl.cfs.nrcan.gc.ca/seed-centre/seed-center-e.htm

Convention on Biological Diversity: www.biodiv.org

DANIDA Forest Seed Centre: www.dfsc.dk

DANIDA Forest Seed Centre, glossary of seed biology and technology: www.dfsc.dk/TN59.pdf

European Centre for Nature Conservation: www.ecnc.nl

European Environmental Agency: www.eea.eu.int

FAO Forestry Internet site: www.fao.org

Fire effects information: www.fs.fed.us/database/feis

Information on California plants for conservation, research and education: www.calflora.org

International Center New Forests Projects: http://www.newforestsproject.com/

International Plant Genetic Resources Institute: www.ipgri.cgiar.org

International Seed Testing Association: www.seedtest.org

International Union of Forestry Research Organitations: http://infro.boku.ac.at

Internet Directory for Botany University Departments: http://www.botany.net/IDB/subject/botherb.html

Internet Links for Botany and Plant Ecology:

http://www.westminster.edu/staff/athrock/ECOLOGY/Botlinks.htm

Institute of Dendrology, Polisch Academy of Sciences: www.idpan.poznan.pl

ITIS, Integrated Taxonomic Information System: www.itis.usda.gov

Jardin, le serveur des jardiniers amateurs: www.jardin.ch

Native plants journal: http://nativeplants.for.uidaho.edu

Net Forêt - Photothèque de la filière bois - forêt, pour les forestiers: http://www.albums.netforet.com/

Nursery Technology Cooperative Homepage: www.cof.orst.edu/coops/ntc/ntc.html

Phoenix Tropical Gardens: www.desert-tropicals.com

Planta Europa: http://www.plantaeuropa.org/

Plants National Database: http://plants.usda.gov/

Proceedings of Past US Forest Nursery Association Meetings: http://www.fcnanet.org/

Reforestation, Nurseries and Genetic Resources: www.rngr.fs.fed.us

Research and Biodiversity Interest Group: www.gencat.es/mediamb/biodiv/rbigdesc.htm

Royal Botanical Gardens of Kew: www.rbgkew.org.uk

Royal Botanical Gardens of Kew, Seed Information Database: http://www.rbgkew.org.uk/data/sid/

Royal Botanical Garden of Sidney: www.rbgsyd.gov.au

Royal Horticultural Society: www.rbg.org.uk

Seed Science Research: http://hort.cabweb.org/SeedSci/ssr_home.htm

Tom Landis's Images: http://www.forestryimages.org/browse/autimages.cfm?aut=1715

United Nations Convention to Combat Desertification: http://www.unccd.int/main.php

University of Ohio: www.hcs.ohio-state.edu/plants

USDA Agriculture Research Service: www.ars.usda.gov/is/index.html

USDA Forest Service Data and Information Systems: http://www.fs.fed.us/database/

USDA Forest Service, National Tree Seed Laboratory: http://www.ntsl.fs.fed.us

USDA Forest Service, Woody Plant Seed Manual: http://www.wpsm.net

USDA Natural Resources Conservation Service, Plants Data base: http://plants.usda.gov

8. Glossary

ACHENE. One-seeded, dry, indehiscent fruit, formed from one carpel.

AFTER-RIPENING. The physiological maturation processes which occur in e.g. seeds and fruits after harvest or abscission. After-ripening is often necessary for immature seeds to become germinable. Also used for the seed handling process itself.

AGAMIC. See V*egetative propagation*.

ALIEN. An introduced species.

ALLOCHTHONOUS. A non-indigenous species; the opposite of autochthonous.

ALLOGAMY. Cross-pollination, which may occur when pollen is transferred to flowers on the same plant or to flowers on other plants of the same species.

ALLOPATHY. The capacity of some vegetable substances released into the ground to exercise negative effects upon the germination of other species.

ALOPHYTES. Plants that live in environments and substrates rich in salt. Their resistance towards salinity is due to a particular plasmatic structure and to a reduced transpiration surface; or to special osmotic behaviour or a particular capacity that enables them to eliminate excess salt by excretion.

ANEMOCHORY. Seed dispersal by the wind.

ANGIOSPERMS [angio=cover, sperm=seed]. Flowering plants; sub-division of *Spermatophytae*, the seed plants. Distinguished from the other sub-division, *Gymnospermae*, by having the ovules borne in an ovary. After fertilisation the ovary becomes a fruit, enclosing the seeds. The group includes among woody plants bamboos, palms and most species of forest trees. The term 'hardwood' is sometimes used synonymous to angiospermous trees although the wood is not always harder than that of gymnosperms ('softwood'). They are subdivided into two classes: Monocotyledons and Dicotyledons.

APHYLLIA. Precocious loss of leaves to perform photosynthesis through the young still green, trunks. A characteristic of several shrub and tree species of *Leguminosae* typical of Mediterranean vegetation (brooms).

APOMIXIS. Production of seeds without fertilisation.

ARIL. Outgrowth on the surface of certain seeds. Normally a distinction is made between *true aril* which is an outgrowth of the funiculus and *arilloid*, an outgrowth from other parts of the seed. The aril is usually fleshy and nutritious and serves to attract dispersers. Arils may enclose the seed partly such as in *Afzelia* and *Taxus*, or completely such as in *Podocarpus* and *Durio*.

AUTOCHORY. Dispersal of seeds by the plant itself; self-seeding.

AUTOCHTHONOUS. Relating to a species or a population native to the site.

AUTOGAMY. Self-fertilization or self-pollination

AUTUMN SOWING. A practice that makes it possible to cold stratify under natural conditions but the lengthy period spent by the seed in the ground may give rise to risks deriving from animal depredations, spring frosts, etc. If the seeds are small (alder, etc.) and they are not very deep in the ground, any marked changes of temperature may dry the surface of the ground and lead to damages.

BERRY. Fleshy fruit developed from a single pistil and with no hard layers in the pericarp. The fruit is usually many-seeded, but one-seeded berries occur in e.g. *Persea* (avocado).

BIOCENOSIS. The living organisms found in an ecosystem.

BIODIVERSITY. Abbreviation of biological diversity; it represents the variation between the living organisms that make up, *inter alia*, terrestrial and aquatic ecosystems and the ecological complexes to which they belong. Biodiversity is defined on three levels: genetic (all the forms existing within the same species), species (the diversity existing between different species), of ecosystem (the different ecosystem where the organisms live).
In other words, it is the total variability between the species of all living organisms and their habitat.

BOLOCHORY. Dispersal of seeds performed by the plant itself (self-seeding) by ejecting the seeds for a certain distance. It is a way of autochory.

CAPSULE. Dry, usually many-seeded dehiscent fruit composed of two or more fused carpels that split at maturity to release their seeds, e.g. *Swietenia* and *Eucalyptus*. Capsules may have one or more rooms (locules).

CLIMAX. A biotic community that is in equilibrium with existing environmental conditions and represents the terminal stage of an ecological succession.

COATING. The operation of covering the seed with inert substances, often vehicles of pesticides, and water soluble adhesives until the product resembles a pellet. It will melt or break in contact with water, freeing the seed. Synonim of *Pelleting.*

COTYLEDONS. In seeds, the embryonic leaves, which in many species have absorbed the entire or the major part of the nucellus and endosperm, hence becoming the principal nutrient storage tissue. Monocotyledons have one, dicotyledons two and conifers often many cotyledons. During germination the cotyledons may remain underground (hypogeal germination) or be pushed above the soil to become the first photosynthesising leaves (epigeal).

CRYOPRESERVATION. Maintaining tissues or seeds for the purpose of long time storage at ultralow temperature, typically between -150°C and -190°C (usually in liquid nitrogen). In normal cryopreservation the sample is pre-treated with a cryoprotective substance, followed by slow, controlled freezing.

CRYPTOGAM. An expression that has no taxonomic value but indicates plants that do not have flowers and reproduce by means of spores.

CULTIVAR. A set of cultivated plants distinguished by certain common features (form, organic/chemical function) and which keep their distinct characteristics when they are reproduced by sexual means.

DEHISCENCE. The splitting open of an anther or a dry fruit to discharge its content. In fruit terminology dehiscent fruits are those that split open at maturity upon drying, usually while still attached to the plant, e.g. capsules, follicles and some pods. Ant. *Indehiscence.*

DEPULPING. Extraction of seeds or stones by removal of the fleshy part (pulp) of fruits like berries and drupes. Depulping may be carried out by soaking and fermentation followed by pounding, maceration or mechanical treatment e.g. by coffee depulper.

DESICCANT. Chemical compound that has a high moisture absorption affinity and can be used for desiccation or maintaining a low humidity when stored together with e.g. seeds. Common desiccants are SiO, CaO.

DESICCATION SENSITIVE. About seeds which do not tolerate drying below a certain (high) critical moisture content. Often used equivalent to *recalcitrant.*

DE-WINGING. Removal of the wing from winged fruits or seeds by slight hydration (pine seed), tumbling or brushing, or manually.

DICLINY. Separation of male and female reproductive structures into different flowers. Diclinous plants may be either monoecious or dioecious.

DICOTYLEDONS. See *Cotyledons*

DIOECIOUS [di = two, oikos = house]. Species with male and female sexual reproductive organs borne on different individuals; e.g. rattan species. See *Dicliny*.

DIPLOID. Cell or organism with two basic chromosome sets, symbolised by 2n; the condition of the vegetative tissues of most higher plants. See *Haploid.*

DISPERSAL. For seed: the physical removal and displacement of the dispersal unit (diaspore) from the mother tree to some distance away longer than vertical falling. Dispersal in forest trees is usually by wind (anemochory) or animals (zoochory). Time of dispersal usually coincides with maturity and hence seed harvest.
In temperate climates, the woody species wind dispersed do not usually possess any dormancy, or only a slight dormancy. On the other hand, when dissemination depends on mammals or birds, the seeds usually require complex treatments before germination, especially in the case of plants living in the understory (*Amelanchier, Cornus, Ilex, Juniperus, Mespilus, Pyrus, Styrax, Taxus, Viburnum, Zizyphus,* etc.).

DORMANCY. Physiological state in which a viable seed fails to germinate when provided with water and environmental conditions normally favourable to *germination*. It is a genetically controlled characteristic that interacts with environmental factors in various ways.
The different types of dormancy have been simplified by Baskin and Baskin(1998):

Type	Cause	Broken by
Endogenous dormancy		
Physiological	Physiological inhibiting mechanisms (PIM) of germination	Warm and/or cold stratification
Morphological	Underdeveloped embryo	Appropriate conditions for embryo growth
Morphophysiological	PIM of germination and underdeveloped embryo	Warm and/or cold stratification
Exogenous dormancy		
Physical	Seed or fruit coats impermeable to water	Scarification
Chemical	Germination inhibitors	Leaching
Mechanical	Woody structures restrict growth	Scarification / Warm and/or cold stratification

DRUPE. Fleshy fruit consisting of an outer exocarp (fruit skin), a mesocarp (usually of fleshy or leathery substance) and an inner hard endocarp enclosing one or more seeds. The outer part is usually removed during processing leaving the endocarp with enclosed seeds (stone or pyrene) as the storage unit. Some drupes have dry rather than fleshy mesocarp, e.g. coconut and teak.

DRY FRUITS. Category of fruits which dehydrate or dry during maturation. Drying often causes dehiscence (opening) of the fruit and release of seed. Dry fruits are e.g. capsules, pods, follicles, cones and some aggregate and multiple fruits.

ELAIOSOME. Oil-rich outgrowth on seed or fruit which is eaten by ants, but also birds, and thus serves to disperse the seed.

EMBRYO. The non-self-supporting immature organism formed from the zygote by cell division and differentiation; the rudimentary plant within the seed.

ENDEMIC. The term refers to the characteristic of those species which naturally occupy a specific region and whose distribution is comparatively limited.

ENDOZOOCHORY. Seed dispersal by animals that eat (ingest) the fruit and void the seed by regurgitation or in their faeces.

EMPTY SEED. Seed without any content, or without an embryo or embryo cavity if some residual tissue is present.

ENDOCARP. Inner layer of the pericarp (fruit wall); e.g. the hard part of drupe fruits like in *Olea.*

ENDOSPERM. Term usually reserved to the triploid nutrient storage tissue surrounding the embryo in seeds of angiosperms. Sometimes also used for the haploid storage tissue of gymnosperms which is derived from tissue associated with the female gametophyte. The endosperm is normally hard at seed maturity but remain liquid in coconuts. In many seeds the endosperm is digested by the developing embryo.

EPICOTYL. The shoot end of the embryo which develops into the stem. In germinated seeds or seedlings referring to the portion of the stem between the cotyledons and the first leaves.

EPIGEAL GERMINATION. See *Cotyledons*.

ETIOLATION. The appearance of plants growing in the dark. The plants lack chlorophyll and are therefore pale. They develop long slender stems and have rudimentary leaves.

EXOCARP. Outermost layer of pericarp; the skin on fleshy fruits as in *Cornus*, *Malus* and *Prunus*. Sometimes called *epicarp.*

FERMENTATION. Anaerobic (without oxygen) decomposition of organic material. The chemical equation for simple alcoholic fermentation is: $C_6H_{12}O_6$ _ $2C_2H_5OH + 2CO_2$. Fermentation may be caused by the catalytic action of a 'ferment', which may be an independent organism such as yeast or bacteria, or an enzyme. It may be accompanied by the production of heat and of toxic substances, and the fermentation of fleshy fruits may adversely affect the seeds which they contain.

FLESHY FRUITS. Fruits are often classified as dry or fleshy types. In fleshy fruits the seeds are surrounded by or imbedded in a fleshy, usually sweet substance with a high water content. They include fruit types such as berry, pome, drupe and some aggregate and compound fruits. Fleshy fruits are normally dispersed by animals (zoochory). They usually change colour and develop sweet taste and/or smell upon maturity to attract dispersal agents.

FOLLICLE. Dry dehiscent fruit formed from a single carpel, splitting along one side only, e.g.

Grevillea. Some aggregate fruits are made up of single fruits of follicles, e.g. *Manglietia* and *Magnolia*.

FRESH SEED. Seed that has been recently collected and has not been stored.

FRUIT. In a strict botanical sense, the mature pistil or pistils of the angiosperm flower, in some types is also included associate structures like receptacle or perianth. In a less strict terminology it includes the mature seed-bearing organs in gymnosperms, e.g. cones, multiple and aggregate fruits. Fruit wall (pericarp) is sometimes divided into three separate layers viz. *exocarp*, *mesocarp* and *endocarp*.

FRUITING. The phenological period from end of flowering to fruit maturity and dispersal. In common terminology often referring to the period of fruit maturity only i.e. fruit collection or harvest. Also used for gymnosperms with no fruits in the strict botanical sense.

GAMETE. Reproductive cell whose nucleus and often cytoplasm fuses with that of another gamete (fertilisation), the resulting cell (zygote) developing into a new individual. Gametes are haploid. In higher plants the gametes are differentiated into female gamete (egg cell) and male gamete (sperm cell).

GAMETOPHYTE. That plant generation which produces gametes from which, after fertilisation, thesporophyte develops. The gametophyte has haploid (n) chromosome number.

GERMINATION. The physiological processes in the first stages of growth of seed (and pollen grain). In seed germination, resumption of active growth in the embryo of a seed is demonstrated by the protrusion of the radicle. In seed testing (International Seed Testing Association definition), resumption of active growth in an embryo which results in its emergence from the seed and development of those structures essential to normal plant development.

GERMINABILITY. In a general sense, the ability to germinate. It is sometimes used as a synonym of *germination capacity*.

GERMINATION CAPACITY (= GERMINATION PERCENTAGE). Proportion of a seed sample that has germinated normally in a specified test period, usually expressed as a percentage. It should be noted that in earlier literature the term 'germination capacity' has been used to express viability.

GERMINATION ENERGY. The proportion of germination which has occurred up to the time of peak germination, or the time of maximum germination rate, or up to some pre-selected point, usually 7 test days. The critical time of measurement can be chosen by several means.

GERMINATION PERCENTAGE. See *Germination capacity.*

GERMINATION TEST. Standard test carried out to determine the quality of a seed lot, i.e. the percentage of germinable seeds. The germination test is carried out under prescribed standard conditions under the, for the particular species, optimal germination conditions of temperature, humidity and light. Dormant seed must be pre-treated in order to break dormancy before the germination test.

GYMNOSPERM [gymno=naked, sperm=seed]. Botanical classification of the group of vascular seed plants in which the ovule (and later the egg) is not enclosed in an ovary (as different from angiosperms). Most gymnosperms produce seeds in cones (common name conifers). Noncone-producing gymnosperms are e.g. *Podocarpus*, *Ginkgo* and *Taxus*.

HABITAT. The type of place or site in which an organism or an entire population lives in its natural state.

HAPLOID. Cell or organism with one basic chromosome set, symbolised by n; the normal condition of gametes, i.e. egg cell and sperm cell.

HARD SEED. Seeds with hard, impermeable seedcoat that prevents imbibition. The hard seedcoat also serves as protection against physical damage. In order to make hard seeds imbibe and germinate, the seedcoat must be perforated, e.g. by scarification.

HERMAPHRODITE (= bisexual, monoclinous). Having functional male and female reproductive organs in the same flower.

HYPOCOTYL. The axial part of the embryo between the cotyledons and the radicle. In seedlings, the juvenile stem which is between the cotyledons and the root system.

HYPOGEAL GERMINATION. See *Cotyledons*.

IMBIBITION. The process of initial water uptake by seeds prior to germination. Imbibition is an entirely physical process and also non-viable seeds imbibe.

IMMATURE EMBRYO. Seed embryo which has not attained a development stage to make it capable of germination.

INDEHISCENT. Remaining closed at maturity. The opposite to *dehiscent*.

INDIGENOUS. Species native to a country or an area, not introduced. The contrary of *exotic*.

INFLORESCENCE. Flowering shoot; the assembly of a few or many individual flowers into large clusters from a common axis. Inflorescences are grouped according to the manner of branching.

INFRUCTESCENCE. Fruit stand; cluster of fruits or arrangements of fruits on a plant.

INHIBITION. Restraint or repression of a seed function, e.g. inhibitory substances in a fruit or seed restraining or repressing seed germination.

INHIBITOR. Chemical compound which inhibits germination, e.g. coumarin and abscisic acid (ABA)

INVASIVE SPECIES. Species that can move into an area and become dominant numerically or in terms of cover, resource use, or other ecological impacts.

ISTA (INTERNATIONAL SEED TESTING ASSOCIATION). International association which issues rules and regulations for standard seed testing on agricultural, horticultural and forest tree seed. Revised and updated rules and regulations are issued every three years. ISTA rules are mainly followed in Europe,Africa and Asia, while a slightly different system is used in North and part of South America.

LEGUME. Generally referring to fruits of the family Leguminosae, here used equivalent to 'pod'. Some *Leguminosae* have, however, modified fruit types such as samaras or follicles. The term should be reserved to the prevalent fruit type in *Leguminosae* viz. a multi-seeded dry fruit that may or may not open at maturity.

LEGUME SEED. Seeds of the plant family *Leguminosae*. The seeds are often hard and impermeable. Seed-coat consists of three distinct layers of which the outer two, the cuticle and the palisade layer provide impermeability to water and protect against desiccation.

MACERATION. The process of softening (fleshy fruits) by steeping in a liquid, with or without heat; to wear away or separate the soft parts, by steeping.

MESOCARP. Middle layer of the pericarp; the pulp of berries and drupes.

MIRMECOCHORY. Dispersal performed by ants.

MOISTURE CONTENT (M.C.). The amount of water present in a material, e.g. wood, soil or seed. It is normally expressed on a weight basis, either as the weight of the water in % of the material's oven-dry weight ('dry-weight basis') or, preferably in the case of seeds and fruits, as a % of the material's fresh weight including water ('wet-weight' or 'fresh-weight basis').

MONOCOTYLEDONS. See *Cotyledons.*

MONOECIOUS[mono = one, oikos = house]. A species with male and female sexual reproductive organs borne on the same individual. The opposite of *Dioecious.*

NAKED STRATIFICATION. Pre-chilling of seeds without the use of a moisture-holding medium.

NUMBER OF SEEDS PER KILOGRAM. The number of seeds in one kilogram of material suitable for storage, given a suitable moisture content and with 100% purity.

NUT. Fruit derived from more than one carpel but in which all but one or few ovules abort, leaving the fruit one or few-seeded. Nuts have hard pericarp and the seeds very thin testas, e.g. *Quercus* and dipterocarps.

ORNITHOCHORY. Dispersal performed by birds.

ORTHODOX SEED. Term used to describe seeds which can be dried down to a low moisture content of around 5% and successfully stored at low or sub-freezing temperatures for long periods. There is practically no metabolism in dry, cooled orthodox seeds, but they may deteriorate by general ageing and thus ultimately lose their viability. The opposite of *Recalcitrant.*

OVARY. The part of the pistil that contains the ovules and ripens to form the fruit.

OVULE. A structure in seed plants consisting of the nucellus which contains the female gametophyte,one or two integuments and the funiculus. After fertilisation of the egg cell the ovule differentiates into the seed.

PARTHENOCARPY. Development of a fruit without viable seed. The fruits may be either seedless or seeds may lack embryos. May result from a failure of pollination, a failure in fertilisation, or a failure in embryo development.
See *Empty seed.*

PARTHENOGENESIS. Reproduction from an unfertilised egg, a type of apomixis. See *Apomixis.*

PELLETING. Procedure by which individual seeds are provided with an envelope of adhesive material containing e.g. nutrients, microsymbiont inoculant and/or pesticides. In addition to providing these beneficial compounds, pelleting facilitates mechanical sowing because of the more uniform seed size. Synonim of *Coating.*

PERICARP. Wall of a ripened ovary i.e. fruit wall. The pericarp is homogeneous in some genera and in others it is composed of three distinct layers: exocarp, mesocarp and endocarp.

PLUMULE. The embryonic shoot derived from the epicotyl. In dicotyledons situated between the cotyledons.

POD. *See Legume, Legume seed.*

POLLEN. The male gametophyte of seed plants produced in the anther or in strobili. Wind pollinated species have a large production of light (in conifers usually winged) pollen. Animal pollinated species often have sticky pollen.

POME. Many-seeded fruit derived from a compound pistil embedded in a fleshy hypanthium (cup-shaped receptacle in perigynous flowers) or floral tube of epigynous flowers. E.g. apple.

PRE-CHILLING. Cold moist pre-treatment specifically applied to dormant seed and designed to overcome some types of dormancy. Synonim of *cold stratification.*

PREGERMINATED SEED. A seed at the earliest stages of germination, usually following some treatment. It usually shows cracked seed teguments and/or the radicle.

PRE-TREATMENT. Any kind of treatment that precede the sowing applied to seeds to overcome dormancy and hasten germination, e.g. *cold or warm stratification*, *scarification.* It is sometimes used as a synonym of treatment.

PRIMING (OSMOTIC). Pre-treatment to promote rapid and uniform germination. The seeds are soaked in a liquid solution (e.g. polyethylene glycol (PEG), sugar or salt) of sufficiently low water potential to regulate moisture content at a level where the germination process initiates but radicle protrusion is prevented.

PROCESSING, SEED. Seed handling methods from collection to storage, usually a collective term applied to extraction, cleaning and drying.

PROVENANCE. The place in which seeds, from indigenous or non indigenous stands of trees, were collected.

PURE SEED. That component of a seed lot which consists of seeds of the designated species. According to ISTA rules, it includes not only mature, undamaged seeds but also undersized, shrivelled, immature and germinated seeds provided they can be positively identified as the designated species, and pieces of seed resulting from breakage which are more than half their original size.

PURITY. Proportion of clean, intact seed (according to pure seed definition) of the designated species in a seed lot, usually expressed as a percentage by weight.

RADICLE. The embryonic root, i.e. the part of the seed embryo that develops into the primary root. In seeds, the radicle is always facing the micropyle.

RECALCITRANT SEED. Term used to describe seeds that cannot survive drying below a relatively high moisture content (30-40%) and, for tropical species, do not tolerate low temperature. The seeds rapidly lose their viability and cannot be successfully stored for long periods. The opposite of *Orthodox.*
Recalcitrant seeds are usually heavy owing to the moisture content, which can vary between 30 and 70%; they are comparatively large.
It is supposed that germination commences in these seeds at the very moment of dispersal, and this accounts for the damage caused by any lowering of their moisture level. Since the embryo in some cases may bear a more marked loss of humidity than the whole seed, it is thought that controlled dehydration followed by cryopreservation in liquid nitrogen is a promising technique for storing the germoplasm of species that have recalcitrant seeds.

Techniques have been devised for some temperate zone recalcitrant seeds (*Quercus* spp.) that can maintain viability for 3-5 years: the naked seeds, or mixed with dry peat, are stored at –2°C in containers allowing gas exchange.

RHIZOBIUM. Bacterial root symbiont that infects roots of plants of the family Leguminosae. During infection the plant forms root nodules, in which the bacteria fix atmospheric nitrogen which benefits plant growth.

SAMARA. Dry, indehiscent, winged fruit with one or more seeds.

SCARIFICATION. Disruption of hard seedcoats, usually by mechanical abrasion or by brief chemical treatment in a strong acid, to increase their permeability to water and gases, or to lower their mechanical resistance. Physical scarification is usually performed with hot water.

SCLEROPHYLLOUS. Evergreen plants adapted to life in arid locations; they are provided with thick, coriaceous leaves, usually small.

SEED. In the strict botanical sense, the mature ovule, consisting of an embryo, and possible nutritive tissue, enclosed by the protective seedcoat derived from the integuments. In a broad sense, the term refers to the whole dispersal unit (diaspore or disseminule), e.g. in indehiscent fruits, to the morphological seed (as defined above) plus the whole or part of the fruit that continues to enclose the seed during processing and handling, e.g. samara or nut.

SEEDCOAT. Protective outer layer(s) on a seed derived from the integuments. When two layers of the seedcoat are distinguishable, the terms testa for the outer coat and tegmen for the inner is often used.

SEEDLING. Plant produced from a seed as different from plants produced by vegetative propagation. The latter are called cuttings, stumps, or plantlets depending on mode of propagation.

SEED LOT. A specified quantity of seed of the same species, provenance, date of collection and handling history, and which is identified by a single number in the seed documentation system.

SEED QUALITY. General term that may refer to the purity, physiological quality (germination percentage, vigour) and genotypic quality of a seed lot.

SOIL SEED BANK. Dormant, viable seeds of one or several species accumulated in the soil over one to several years.

STORABILITY. Potential life time of seed under optimal storage conditions (longevity).

STRATIFICATION. Pre-treatment of dormant seeds by storing them for a prolonged period in an imbibed stage at a certain temperature. Cold, moist stratification refers to the traditional pretreatment of temperate seeds by storing the imbibed seeds under cold conditions (originally in alternate layers with a moist medium). Under warm (+20°C), moist stratification the seeds are kept at a temperature of physiological activity; this practice is used e.g. to after-ripen seeds.
The soft, moist medium is generally made of peat, agriperdite, sand or vermiculite, used alone or mixed together in various proportions. The volume ratio of seed/substrate may very from 1:1 to about 1:3. In some cases, it may prove more practical to mix seeds and substrate directly. Very small seeds, or those of a similar colour to the substrate, should be arranged between sheets or other permeable materials so that they are easier to recover when the treatment is finished.
As said above, stratification carried out at low temperatures (between +2°C and +6°C), in controlled environments (refrigerators, cold-storage-rooms, etc.) or in the open air (tanks, ho-

les dug in the ground, etc.) is called cold stratification; in both cases it is essential to maintain a good level of moisture in the substrate, avoiding stagnant water, and ensuring constant and uniform temperatures throughout the seed mass. For open-air treatments, where considerable alterations in temperature and humidity are more likely, it is advisable to irrigate when necessary, ensuring the drainage of the water, and to insulate the seed heap, arranging it in rather deep holes or in places out of the sun, under a layer of insulating material (soil, sand, jute, hessian, leaves, etc.) For reasons of space, large seeds (walnuts, hazel nuts, acorns, etc.) are generally stratified in this way; they must also be adequately protected from rodents, by means of nets, poisoned bait and repellents.
In order to control any fungi present in the seedcoats, since they find conditions that encourage their development in stratification, the seed may be immersed in a fungicidal solution.
Since cold stratification is very much more widespread, when the term stratification is used without specifying whether it is warm or cold, cold stratification is meant.
The advantageous action of thermal treatments (warm-damp, cold-damp or an alternating combination) on the germinative process is evident in several important effects: removal of the different types of dormancy, increased rate and uniformity of germination and total germinability, a wider range of temperature within which germination is possible, less light is required for those species in which germination is favoured by this factor, and a reduction to the minimum of the qualitative differences found in seeds (arising from differing techniques of collection, handling and storage).
Generally speaking, stored seeds require longer periods of stratification than those applicable to recently collected seeds. On the other hand, samples showing low vigour should be subjected to shorter periods of stratification than those referred to in the literature.

STRATIFICATION OF SEED WITHOUT A MEDIUM. Stratification of the seed by itself (naked), usually after being soaked in water for 24-48 hours and then drained.
For this purpose, the seeds are usually arranged in plastic sacks, not airtight so that gas exchange may occur, in a temperature-controlled environment (refrigerator). It is advisable to place no more than 10-12 Kg. of soaked seed in each sack and stir the contents occasionally. Emanation of an odour of alcohol after a period of cold stratification indicates anaerobic respiration resulting from restricted aeration.
Many species (*Pseudosuga menziesii*, *Alcus cordata*, etc.) respond well to this kind of treatment, without any type of health problem arising. Obviously, stratification of the seed without a substrate saves space and simplifies manual operations, so it is preferable to traditional systems whenever it proves effective.

SUCCESSION. The gradual, somewhat predictable process of community change and replacement leading toward a climax community; the process of continuous colonization and extinction of populations at a particular site.

TOPOPHYSIS. The position, in the mother plant, of a particular organ or tissue (afterwards used for vegetative propagation).

VEGETATIVE PROPAGATION. The production of plants without the fusion of gametes, i.e., by means of cuttings, grafting, micropropagation, etc. It permits more or less rapid reproduction of a complete specimen, with characteristics identical to those of the specimen from which the material has been taken.

VIABILITY. Seeds which are capable of germination when given water and appropriate environment (including breakage of possible dormancy) for reactivation of their biochemical processes are said to be viable. Viability tests are not necessarily the same as germination tests since viability may be measured indirectly by e.g. cutting test or staining.

VIABLE SEED. A seed which can germinate under favourable conditions, provided that any dormancy that may be present is removed.

VIGOUR. The seed properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions. Loss of vigour normally foregoes loss of viability, hence showing a steeper decrease (e.g. as measured in a germination test under stress) than viability (e.g. measured under optimal germination conditions).

ZOOCHORY. Dispersal of seeds performed by animals.

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10. Subject and taxonomic index