Propagation Manual of Selected Gymnosperms

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FOREWORD

Although this manual is designed for the advanced amateur, the authors sincerely hope that professional propagators will find information of interest to them within its pages.

With the amateur in mind, the manual is prefaced by a discussion of common propagating techniques and appended by a glossary of propagating terminology. It is hoped that readers will refer to these whenever questions arise as they use the manual.

The genera treated are arranged alphabetically. Recommendations for propagation are general for the genus, unless otherwise specified. In some cases, experience with propagation of a genus has been limited at the Arnold Arboretum because the species are not hardy in the Boston area. Efforts to gather propagating information on these plants were frequently disappointing, and contributions from readers will be welcomed. Brief bibliographies follow the propagating information on each genus. These by no means are complete, but may suggest directions for further research on the part of both amateurs and professionals.

The nomenclature used follows that of Den Ouden and Boom.

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Male and female cones of Abies koreana. *Fertilized cones will mature in autumn of their first year. Photo: H. Howard.*

INTRODUCTION

Botanists divide seed-bearing plants into two groups — angiosperms and gymnosperms.

Angiosperms bear true flowers and fruits. The male reproductive structure is the stamen. The female reproductive structure consists of one or more carpels. The usually enlarged base of the carpel, termed the ovary, contains ovules which, when fertilized, develop into seeds. As these mature, the ovary also undergoes structural changes and, at maturity, is termed the fruit. The seeds are enclosed within the fruit or ripe ovary, and are called angiosperms or enclosed seeds.

Gymnosperms do not bear flowers or fruit, though their reproductive structures can be roughly equated to those of angiosperms. Pollen is borne on modified structures called microsporophylls. These occur in small, cone-like clusters on branches and are often incorrectly referred to as male "flowers." There is no real carpel or ovary in the female reproductive structure of the gymnosperms. Instead, the ovules usually are borne either singly or in pairs on the surface of structures called megasporophylls. As a result, the ovules are exposed, or "naked," and are called gymnosperms or naked seeds. After fertilization, the ovules develop into seeds and the megasporophylls also undergo structural changes. The familiar pine cone is an aggregation of megasporophylls, while the fleshy red structure that partially encloses the seed of *Taxus* is a single megasporophyll. Since gymnosperms have no carpels, their reproductive structures technically cannot be called "flowers" or, when ripened, "fruit," and in this manual they will be called "cones."

Gymnosperms may be propagated in two ways — by seedling (sexual) or vegetative (asexual) reproduction. Seedling reproduction is generally more economical, but it allows for genetic variation among the propagants and usually requires more time to develop usable plants. However, seeds and seedlings are uniform enough in size that they can be handled by mass production techniques. This is of importance to growers producing large numbers of plants.

Vegetative propagation eliminates the problem of genetic variation since propagants identical to the parent plant, that is, maintaining their unique characteristics, are produced.

SEXUAL PROPAGATION

Limitations of Seedling Propagation

Genetic Variation of Seedlings

The horticultural characteristics of a plant are determined by its genetic make-up. They can be altered by recombination or mutation of the genes. Variation among cultivars of some plants such as false-cypress (*Chamaecyparis*) seems to be derived from both recombination and mutation; that of others, like hemlock (*Tsuga canadensis*), is largely derived from genetic recombination.

Each gene affects the expression of some characteristic of the plant. In many cases, the effect of the gene is hidden for many generations until recombination allows it to be expressed. Recombination occurs only in the sex cells, prior to fertilization of the ovule with pollen. Therefore, variation due to recombination occurs only among seedlings.

Mutation, on the other hand, may alter horticultural characteristics at any time during the life of a plant. Such mutation affects the nature of a gene, so that its expression produces a different characteristic. If mutation occurs at an early stage in plant growth, the entire plant may be affected. More often only a single branch, or even a small part of a leaf, is modified. Generally, mutation affects only one characteristic while recombination has manifold effects.

In nature, genetic variation among seedlings can be advantageous, since it allows a particular species to adapt to changes in the environment. A tall, rapid-growing pine may have a competitive advantage, surviving in a crowded woodland situation where competition for light is intense, while a lower, slow-growing plant may not survive. Seedling variability is also a key factor in the development of new cultivars, and many superior horticultural taxa have arisen this way.

Seedlings of Pinus strobus *(Eastern white pine), show similarity of size. They germinated in unison after two months of cold stratification at 40° F. Photo: P. Chvany.*

However, in cultivation variation may reduce the value of a plant, depending on its intended use. Uniformity of characteristics is especially important for plants used in landscaping. In a hedge or a row of trees, for example, similarity of form, color, texture, and growth rate may be essential.

Sex of Seedlings

In some gymnosperms, male and female cones are produced on different plants. Frequently, one sex is preferred for cultivation. For instance, since large female ginkgos (*Ginkgo biloba*) produce prodigious quantities of foul-smelling "fruits," * male plants are usually grown. Sex of plants propagated by seed cannot be determined until the plant is mature enough to develop reproductive structures. Most gymnosperms do not mature for many years, by which time they are large and occupy prominent positions in the landscape. (The authors know of a specific instance where a ginkgo produced reproductive structures for the first time after twenty-four years.) Therefore, when young plants of a particular sex are required, they must be propagated asexually from clones of a known sex.

Time Required to Produce Plants

Sexual propagation of most gymnosperms is slower than asexual propagation. The seeds of some species require extended periods of pretreatment to break dormancies and seedlings require more time to develop into mature plants than do vegetative propagants. Umbrella-pine (*Sciadopitys verticillata*) seedlings, for example, usually produce only cotyledons, or seed leaves, the first year and several true leaves the second. The whorl of leaves for which the plant receives its name appears during the third year. At this time the seedling has attained a size comparable to that of a cutting taken for propagation.

Advantages of Seedling Propagation

The primary advantage of seedling production is that large numbers of plants can be reproduced easily and inexpensively. This is particularly important for those genera used extensively in reforestation, development of shelter belts, and Christmas tree farming.

Most gymnosperm seed can be stored for at least short periods. The seeds of some "fire" pines (*Pinus attenuata*, *P. contorta*, *P. muricata*, *P. pungens*, and *P. radiata*) remain viable as long as twenty-five years or more in cones on the tree; seeds of *P. contorta* in closed cones have been reported viable after eighty years.

Relatively little storage space is needed for seed of gymnosperms.

Large quantities of seed can be shipped easily and inexpensively to any location in the world, while vegetative propagating material requires special handling and packaging techniques. Many states

* See page 1.

and countries have quarantine barriers against the latter, but will allow seeds to cross their borders since they are less apt to harbor disease organisms and insect pests.

Sources of Seed

After obtaining permission from landowners, small lots of many types of gymnosperm seed may be collected from individual specimens along roadsides and in natural woods. When possible, parent plants should be evaluated for form and other characteristics, and seed taken only from those most desirable. Some botanic gardens and arboreta make seed of unusual plant taxa available upon request.

Large quantities of seed needed by commercial seedsmen and foresters are ideally collected from designated seed production areas where trees have been developed and evaluated for special characteristics. Foresters throughout the world have long recognized the need for selecting superior seed plants. Evaluation of seed trees is especially important for producers of Christmas trees, lumber and paper products, since their trees must be standard for certain desirable characteristics such as size, color, shape, and rate of growth.

In some cases, seed can be purchased from commercial dealers who specialize in controlled storage, handling, and sales. These dealers should specify the place and year of origin, and indicate the percentage of foreign matter.

Where possible, seed from plants of known hardiness should be used, since seed lots vary widely in this respect, depending upon the locality of origin. In most species, distinct strains (termed geographic races) varying in hardiness have evolved. For example, seed of Douglas-fir (*Pseudotsuga menzesii*), collected in the Rocky Mountains, tends to be hardier in the Boston area than seed of the same species collected along the West Coast.

Harvesting of Seed

Harvesting dates depend on the natural agents of dispersal and seed ripeness. Ideally, seed should be collected as soon as it is mature, but before natural agents remove it from the tree.

Natural Dispersal

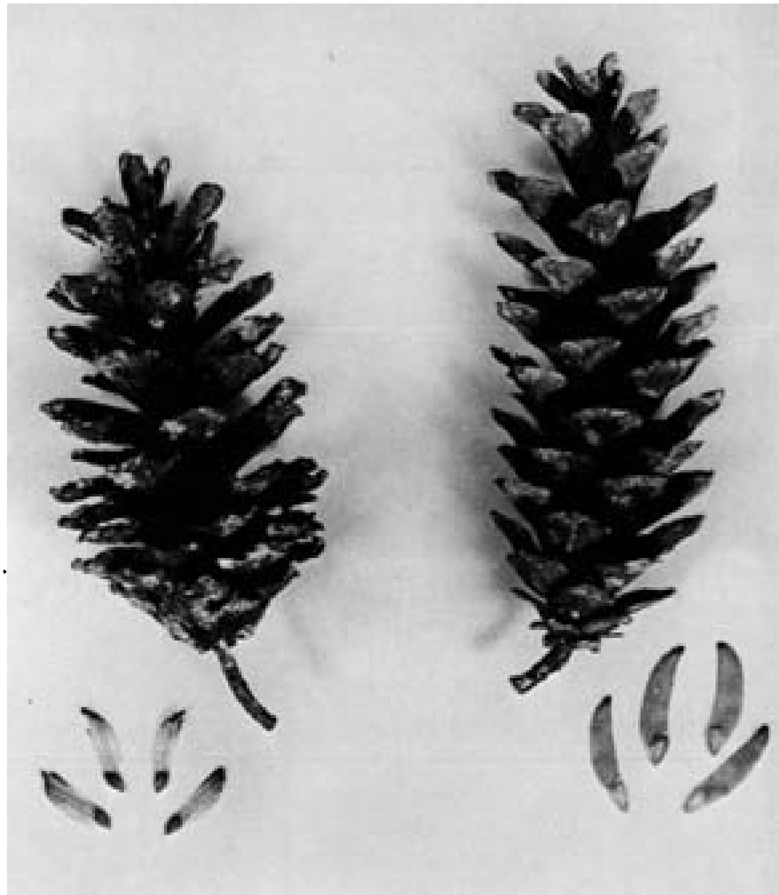
The natural agents responsible for distributing gymnosperm seed are wind, water, birds and animals. Of these, wind is the most important. Most gymnosperms produce light, winged seeds that are whipped from their opening or shattering cones by the wind and carried varying distances, depending on wind velocity and plant location. These seeds also float in water and may be carried far away from the parent plant if they happen to fall into a river or stream. Cones must be collected immediately prior to opening to assure maturity and prevent loss of seeds.

Taxus *reproductive structures comprised of single seed surrounded by a fleshy cone scale open at the apex. They must be collected before they are taken by birds and animals. Photo: H. Howard.*

A few gymnosperms, including yew (*Taxus*), and juniper (*Juniperus*), produce fleshy, succulent cone scales that are eaten by birds and animals. The pulp furnishes food while the hard-coated seeds pass through the vectors' digestive tracts and are scattered about the countryside in their droppings. Migratory birds may carry seeds some distance from their point of origin. Seeds in fleshy coatings that are attractive to wildlife must be collected just prior to the final color change. At this stage, the seeds will have developed enough to be viable, but the immature cones will not appeal to their natural consumers.

Seed Ripeness

In general, seed is ripe when the surrounding structure begins to develop characteristics that lead to natural dispersal. Fleshy cone scales change color and become palatable, attracting vectors. Dry cone scales begin to separate for release of seeds to the wind. No single characteristic can be used to determine the ripeness of all seed. Color and dryness of the cone scales may be used as an indicator of maturity for some species. In others, the texture, color, moisture content, and hardness of the seed itself may suggest ripeness. It is important to know the characteristics that indicate ripened seed for a particular species.



Cones of Pinus strobus *open and release seeds to wind dispersal during late summer of their second year. Photo: H. Howard.*

On a single tree, most gymnosperm seed ripens uniformly, but neighboring trees of the same species may differ, making collection of large seed lots difficult.

Harvesting Techniques

Fallen seed can be collected from the ground if one is certain of its identity. Standing trees present more of a problem, since fruit is frequently borne high on the branches. Often, seed can be shaken free by agitating the tree limbs. Cone hooks with curved metal blades attached to a long light pole may be used to cut cones from high places. Pole shears — two cutting blades mounted on a pole and operated with a line or wire — also may be used. Cones that shatter upon ripening, such as those of the true cedars (*Cedrus*), firs (*Abies*), and golden larch (*Pseudolarix amabilis*), must be hand-collected. Before collecting seed from any one source, a sample should be checked for sound contents.

Cleaning of Fleshy Cones

Because of decay organisms and limitations of storage space, seed should be separated from the fleshy cones as soon as possible after collection. The pulp surrounding most seeds contains inhibitors that prevent premature germination of the seed while it is still attached to the parent tree. This pulp must be removed to permit germination.

In many cases, moist pulp of fleshy cones starts to decompose a few hours after collection. If not controlled, this may lead to seed spoilage and loss of viability, but it is an important first step in the separation of viable seeds. The pulp decomposes into a soft mass that is easily separated from the seeds by maceration and flotation techniques. Disintegration may be hastened by placing the cones in a container and adding a little water. The material should not be allowed to remain in the containers longer than necessary to break down the pulp, since decomposition may cause heat build-up or production of harmful chemicals.

Maceration and Flotation

Seeds and softened pulp may be separated by macerating the mixture gently but thoroughly and placing it in a container of water so that heavy, sound seeds sink to the bottom while the lighter pulp and void seeds float. The pulp mixture and water are then poured off, leaving only clean, sound seeds in the vessel. Tall, narrow containers are especially efficient for flotation as the tall column of water allows wide separation between floating pulp and sound seeds. Two or three washings may be necessary.

Small quantities of fleshy cones may be hand macerated; mess and inconvenience can be avoided by kneading them in a disposable plastic bag. Large quantities are processed in specially constructed macerating machines.

Seeds and macerated pulp are separated by floatation. Sound seeds sink while pulp and void seeds float and can be poured away. Tall narrow vessel allows wide separation of pulp and seeds. Photo: P. Chvany.

Small amounts of fleshy pulp can be separated from seeds by hand-kneading the mass in a disposable plastic bag. Photo: P. Chvany.

At the Arnold Arboretum, a food blender is used to clean small quantities. The blender has been modified by removing its blades since they chop up the seeds. A small square of reinforced rubber, taken from the center of a worn truck tire, has been fastened to the cutter head, concave side up. This rubber square beats the cones effectively without injuring the seeds.

Cleaning of Dry Cones

Cones produced by most gymnosperms must be allowed to dry so that the scales separate and the seeds can be extracted. Air drying of cones spread out in shallow layers takes from one to three weeks, depending on the species, stage of maturity, and atmospheric conditions. It is best done in a location where animals, rain, and wind will not be disruptive. Good ventilation and periodic turning of cones will insure even drying.

Cones of the fire pines open only at high temperatures and are dried in heated kilns by commercial processors. Small quantities of many gymnosperm cones can be opened by placing them in a closed paper bag on a home radiator. Cones of other species requiring greater heat can be dried in the kitchen oven at temperatures not exceeding 130°F.

Some cones (i.e. *Cedrus*, *Abies*, etc.) may be opened by soaking them in water, after which they crumble apart. Wetted cones that fail to open can be frozen out-of-doors in winter, or in a freezing unit. Ice crystals form and force the scales apart.

After opening, cones must be shaken to remove the seeds. Cones and seeds are separated by shaking them in a screen with mesh small enough to retain the cones or scales but large enough to allow passage of the seeds. Commercial seedsmen tumble large quantities of cones in revolving wire cages above containers that catch the seeds.

Fanning and Winnowing

Cones of the firs, true cedars, and golden larch are composed of scales and seeds surrounding a central woody axis. When dry, these shatter and the seeds must be separated from the scales. In some species there is little difference in size between the winged seeds and the scales, and so screening does not work. However, the winged seeds are much lighter and small numbers can be separated by gently blowing the material as it is passed slowly from hand to hand. The scales are retained in the hand while the seeds are carried away to a nearby surface where they can be gathered.

Large numbers of seeds and scales can be separated by placing the material in a screen and bouncing it in the air current of an electric fan. The heavier scales remain in the screen while the seeds are blown a short distance away, where they can be collected later. Some experimentation is necessary to determine how close the screen should be placed to the fan.

Dewinging

Seeds of a number of gymnosperm species are fragile and easily damaged by dewinging. In commercial practice, the wings are removed with specialized equipment that reduces the chance of injury. If small quantities are to be processed, and the seeds are not easily damaged, they can be dewinged by rubbing them between the hands; if the seeds are fragile, they can be sown satisfactorily with wings remaining.

Storage

Many gymnosperms bear seeds sporadically, the intervals between crops varying with climatic conditions and species. Seed crop quantity also fluctuates, with trees producing more seed in some years than in others. Growers who use seed annually must store it from year to year to assure its availability.

Screens of various mesh size are used to separate seeds from cones, cone scales, or extraneous matter. Photo: P. Chvany.

Optimum storage time varies greatly with genus, species, and seed lot. Some seeds can be held for years with little difficulty, while others normally lose viability within a few months. Germinative capacity following storage also is determined by seed viability at harvest and method of storage. The most favorable conditions for storage of any seed species are those that slow natural desiccation and reduce the rate of respiration and other metabolic processes without injuring the embryo. Moisture content and storage temperature appear to be the most important exterior influences on seed longevity.

Moisture Content

Most gymnosperm seed endures long periods of storage best when stored dry. In many cases, the moisture content of seed is affected by the degree of saturation of the immediate atmosphere. Seeds absorb or give up moisture until they are in equilibrium with the surrounding air. Frequently, fluctuations in moisture content caused by variation in the relative humidity are detrimental to seeds and reduce their longevity, but the extent to which relative humidity affects seeds in storage depends upon the species. Ideal storage conditions should maintain atmospheric moisture at levels which insure constant low moisture content of seeds.

In temperate climates, a suitably low moisture content can be achieved by air-drying the seeds. It then can be maintained by storing them in a sealed, vapor-proof container. Polyethylene bags are suitable since they seal tightly and easily, are moisture-proof and allow some exchange of gases.

For short periods, seeds of those species that require cold treatment before germination are best held at high moisture content. They can be mixed with a dampened medium such as sand and peatmoss, and placed in a sealed, vapor-proof container held at about 40° F.

Temperature

As storage temperature drops, viability of gymnosperm seed is prolonged. Temperatures between 33° and 50° F appear to be optimum, although some researchers have noted benefits from storage below 32° F. The family refrigerator is usually set at about 40° F, which is satisfactory for seed storage.

Germination of Seeds

External Requirements for Germination

Germination can occur only when the seeds themselves are ready and when the environment is right. The major factors regulating germination are available water, appropriate soil temperature, sufficient oxygen, and sometimes light.

Permeability of the seedcoat determines the rate at which water is absorbed by seeds. Impermeability is a problem with only a few gymnosperms.

Temperature also can have an important influence on germination of gymnosperm seeds. Some have extremely specific requirements while others germinate over a wide range of temperatures. Most seeds germinate best at temperatures slightly higher than those required for optimum growth following germination. Diurnal temperature fluctuations often result in a higher percentage of germination than does a constant temperature. At the Arnold Arboretum, seeds are sown in late winter or early spring in a greenhouse where the minimum temperature is 70° F. On warm, sunny days temperatures in the house may reach 90° F or more.

Energy used by the seed for germination is provided by a process called respiration. During this process oxygen changes stored sugars, starches, and oils to energy, water, and carbon dioxide. If insufficient oxygen is available in the soil air, germination is inhibited. Lack of oxygen is a problem only if the soil is too wet or compacted, or if the seed is planted too deeply.

Light appears to play a role in the germination of some gymnosperm seeds (i.e. *Tsuga*), while others germinate well in total darkness. Only certain colors of the spectrum are important. Red light promotes germination while far-red light acts as an inhibitor. Since red light penetrates the soil to only about an inch, seeds that have a light requirement and are planted deeper than an inch will not germinate.

Internal Requirements for Germination

Simple or Embryo Dormancy

Seeds of some species, including a few pines and some lots of false-cypress and arborvitae, require no more than a satisfactory external environment (i.e. sufficient water, heat, light, and oxygen) for germination. Other species have internal factors that inhibit germination despite favorable external conditions. Germination may be inhibited by embryos that are not fully developed although the seed appears mature. A period of after-ripening, during which the seed is exposed to cold under moist conditions, usually overcomes this dormancy.

In nature, after-ripening requirements are met by low temperatures and dampness when seeds overwinter out-of-doors. Dormancy is a natural adaptation preventing germination when weather is unfavorable for seedling survival. Without this protection, seeds could germinate during a warm period in late autumn and perish in subsequent cold. Some nurserymen provide natural after-ripening by sowing seeds out-of-doors in the fall and allowing nature to fulfill the cold requirements.

Alternatively, a period of artificial cold may be employed in after-ripening seeds. Stratification is the term commonly used to describe this procedure. The word is derived from the practice of placing seeds in boxes between layers, or strata, of a damp medium before exposing them to cold. Stratification now is interpreted as any process used to encourage germination of dormant seeds that require pretreatment by time and temperature. It tends to hasten and synchronize germination of most gymnosperm seeds, even those that exhibit no dormancy.

Seeds can be stratified by placing them in a refrigerator for a period of time. There is some leeway in refrigeration temperatures, but 40° F has proven satisfactory. Seeds should not be placed in the freezing compartment.

A polyethylene bag is excellent for stratifying seeds since it allows air exchange but prevents water loss. Large quantities of seed can be stratified in barrels, boxes, or cans. Seeds should be layered or mixed in the container with a stratifying medium. At the Arnold Arboretum, a combination of equal parts of sand and peatmoss is used, but other media such as sand and well-weathered sawdust are also satisfactory. The stratifying medium is dampened carefully, since a wet, soggy medium reduces the amount of available oxygen. The volume of the stratifying medium should be no more than two or three times that of the seeds. This is enough to stratify the seeds effectively, but eliminates the need to separate them from the stratification medium before sowing.

Depending on the species, gymnosperms require stratification of one to several months. Stratification should be timed to allow sowing of the seed in the lengthening days of late winter or early spring, when light and temperature conditions are favorable for seedling growth and survival.

Double Dormancy

Sound seeds of some gymnosperms (for example, *Juniperus*) are prevented from germinating by impermeable seed coats that hinder the admission of water, as well as by immature embryos. Such seeds are said to be doubly dormant, since two conditions must be overcome before germination can take place. In nature, it takes two or more years for these seeds to germinate. They often are termed two-year seeds.

In many cases, impermeable seed coats can be altered by a process called scarification, during which the seed coat is modified by scratching and breaking it to allow water penetration. Seeds can be rubbed with sandpaper or scored with a file (mechanical scarification), or they can be placed in strong acid. Impermeability in a number of pines is best overcome by acid scarification. Dry seeds are placed in a glass container and covered with concentrated sulfuric acid. The mixture is carefully stirred periodically with a glass rod and the seed coats checked for degree of erosion. They should be extremely thin, but not eaten through all the way. As soon as they are sufficiently eroded, the acid is poured off and the seeds are washed thoroughly.

Acid scarification should be approached with great care by the amateur since sulfuric acid is highly corrosive and spatters violently upon contact with water. Protective clothing should be worn and used acid should be disposed of outside in unused soil rather than poured down a household drain.

Frequently, the most effective way of breaking down seedcoats is to expose the seeds to a period of warm, moist conditions during which micro-organisms decompose the seed covering. This treatment is called warm stratification, and it must precede cold stratification. For many doubly dormant seeds, a period of five months' warm stratification makes the seedcoat sufficiently permeable for cold stratification to be effective.

The moist medium used for warm stratification must contain some unsterilized material so that micro-organisms will be present. Ordinary garden soil is satisfactory; at the Arnold Arboretum a combination of equal parts of sand and peat moss is used. Sphagnum moss should not be used since it contains a natural antibiotic. Seeds are mixed with the stratification medium, placed in a polyethylene bag, and set in a location where the temperature will fluctuate. Window sills and greenhouse benches are suitable. There is some latitude in temperatures for warm stratification. Temperatures fluctuating between 60° and 100° F have produced good results. Seeds should not be exposed to full sun since this may cause detrimental build-up of heat within the polyethylene bags. Bags should be checked periodically for possible germinating seeds, and the medium dampened if necessary.

Immediately following warm stratification, seeds can be transferred to refrigeration units for cold stratification without opening the bags. When cold stratification facilities are unavailable, doubly dormant seeds can be sown out-of-doors and allowed to experience seasonal temperature changes.

Sowing

Small quantities of seed may be sown in any container that can be sterilized and that provides adequate drainage. Styrofoam cups, plastic flats, and seed pans are suitable. Tin cans with holes punched in the bottom also are quite satisfactory.

Technique for sowing very fine seeds. Even distribution is achieved by tapping the hand holding the folded card in which seeds are placed. Photo: P. Chvany.

The medium used should be loose and well drained, maintaining an even supply of moisture for the germinating seeds. Many excellent prepared and sterilized mixes are available at nurseries and garden centers for reasonable prices. An adequate growing medium can be prepared in the home by combining one part sand, one part loam soil, and one part screened peatmoss.

At the Arnold Arboretum, the growing medium is placed in the container and covered with a layer of milled or screened sphagnum moss. Seed is distributed over the surface of the prepared containers and covered with a second layer of sphagnum. It is not necessary to separate seed from stratification medium.

If the container used is a tall vessel, such as a can, it may be necessary to fill the bottom with a coarse material, such as pot shards or stones, before adding soil medium and seeds. Sphagnum moss or leaves can be placed over the coarse material to prevent the soil mix from sifting through and blocking drainage.

The container should be filled to within ½ inch of the top. Later when the remaining space is filled with water, it provides exactly the volume needed to wet and leach the container's contents thoroughly. To dampen the soil medium initially without disturbing the seeds, the container can be placed in a vessel of water deep enough to reach above the material used for drainage. Capillary action conducts the water upward through the container, wetting its contents. Completed containers are placed on a greenhouse bench or on a window sill.

Watering

Water is one of the most important factors influencing seedling germination. Because germination occurs in the upper surface of the soil medium where the atmosphere has a constant drying effect, maintenance of even moisture may be difficult. Under greenhouse conditions, atmospheric humidity is usually maintained at high levels and drying of the soil surface is greatly reduced. In the home, drying can be avoided by placing the seed pans in polyethylene bags and sealing them tightly. A high humidity is maintained inside the bag and water should not be needed until the seedlings have germinated. It is important that the bag not be exposed to direct sunlight, since this will cause build-up of heat.

After germination, the plastic cover must be removed, as the seedlings become too succulent when grown in a close atmosphere. Rather than remove it all at once, the bag should be opened for lengthening periods over several days to allow the seedlings to become accustomed to a less humid atmosphere.

Disease Control

Gymnosperm seedlings are particularly susceptible to damping-off diseases — fungus-caused disorders that attack seedlings. The fungi invade stem tissues beneath or near the soil surface, causing seedlings to die. These diseases can destroy entire flats in a day and are best controlled by careful, preventive cultural techniques.

Sterile soil and containers are absolutely necessary. Soil mixes can be sterilized by heating them in a 180° F oven for thirty minutes. Insects and most weed seeds will be killed as will most disease organisms. Flats and seed pans can be sterilized by soaking them in disinfectants such as 10 per cent household bleach solution. Clay or metal containers may be heated in an oven or immersed in boiling water to prevent disease problems.

Sowing seed between two thin layers of milled sphagnum reduces the chance of damping-off since its antibiotic properties discourage damping-off fungi. The sphagnum should be unsterilized, since it is a bacterium in the moss that produces the antibiotic.

Stratification of gymnosperm seed hastens and unifies germination, discouraging the development of disease organisms and permitting early separation of the seedlings. Development of fungi can be limited by watering early in the day so that seedlings dry off quickly, and by providing ventilation to evaporate excess water.

If damping-off does occur, drenching with a fungicidal material specific for the purpose will help to reduce losses. A number of highly satisfactory preparations are available.

After-care of Germinated Seedlings

Newly germinated seedlings grow rapidly and soon compete with each other if not separated. They should be moved into pots or flats or lined out in beds where they can develop under uncrowded conditions. Flatting and lining out are preferable to potting since young plants in pots often develop circling root systems that may girdle them in later years. During their first summer, young plants should be provided with shade to protect them from scorching, both in and out of the greenhouse.

In autumn, woody temperate-zone plants go dormant and must be given a period of cold before they will grow again. They should not be planted in the open ground, since repeated freezing and thawing through the winter months causes small plants to heave. A naturally lighted cold storage facility such as a cold frame will give young plants the protection they need, at the same time providing them with the necessary cold period. Attention should be given to venting and shading if the frame is exposed to the sun.

ASEXUAL PROPAGATION

Vegetative propagation is based upon the ability of many plant parts to produce missing essential organs when severed from the parent plant. Shoots can be induced to generate roots, and roots may produce stems and leaves. Separate shoots and roots may, when joined together, form bridging tissue to make one entire plant.

Advantages of Asexual Propagation

Though reproduction from seeds is the most common and natural way of producing plants, there are numerous advantages to vegetative reproduction.

Some gymnosperm species are easier to reproduce asexually than sexually. Many yew seeds, for instance, germinate slowly due to embryo dormancies, yet most taxa of this evergreen root quite easily. Usable plants are produced more quickly and less expensively by asexual techniques.

Plants that produce no viable seed because they are sexually immature, are fixed juveniles, or are dioecious, can be propagated only asexually. Finally, propagants identical to the parent plants can be produced, preserving their unique characteristics and eliminating the problem of genetic variation. Plants derived asexually from a single original plant are all members of a specific "clone" and maintain its distinguishing characteristics. These characteristics may not be duplicated in all of the plant's sexual progeny. Cultivars and hybrids are generally propagated asexually for this reason.

Disadvantages of Asexual Propagation

The only serious disadvantage to asexual propagation is that it may perpetuate a number of plant pathogens (fungi, bacteria, and viruses). Some of these, particularly the viruses, cause permanent changes in the clone, and most affect plant growth adversely. Scrupulous use of disease-free propagating material and tools generally eliminates the problem. Material should be taken only from healthy plants that have developed normally and possess the desirable attributes of the clone. Propagating stock should be examined carefully to determine whether or not it is infected with pathogenic organisms. Attacks by fungi and bacteria usually produce obvious evidence, but the presence of a virus may not be easily detectable in all clones or at all seasons.

Types of Asexual Propagation

Cutting

A cutting is a plant part removed with the intention of inducing it to generate the organs that will allow it to function independently. Propagation by cuttings is usually preferable to grafting because plants are produced on their own roots and the possibility of incompatibility between stock and scion is avoided. No special manual skills are needed for cutting propagation.

Only stem cuttings are important in the propagation of gymnosperms. They are taken from branches or shoots and bear preformed vegetative buds from which new shoots will arise. Roots alone must be generated to turn a stem cutting into a functioning plant.

Stem cuttings may be taken from plants in either hard- or softwood stages. Hardwood cuttings are those taken in fall or early winter from mature shoots that have ceased growth and become woody. Requiring less care than softwood cuttings, they are not especially perishable and can be shipped long distances safely. Most gymnosperms root best from hardwood cuttings.

Softwood cuttings are taken in spring or early summer from new growth of the current season that has not fully matured. Because softwood cuttings are actively growing when severed from the parent plant, they lose a great deal of water to the air through transpiration. Since they have no roots to take up water and replace this loss, the cuttings soon wilt unless placed in an atmosphere of high humidity. Softwood cuttings generally root more quickly than hardwood cuttings; a number of gymnosperms can be propagated in this manner.

Selection of Cutting Material

Cutting material should be taken from plants that are free from disease and insect pests and show normal growth. For best results

vigorous shoots with long internodes should be avoided when possible. Both lateral and terminal shoots may be taken, though there is some evidence that terminal shoots may root less readily than lateral ones. Some gymnosperm species produce diverse plant forms, depending on whether they are propagated from lateral or terminal shoots. For example, only cuttings taken from terminals or upright laterals will reproduce the normal upright form of Japanese yew, *Taxus cuspidata* 'Capitata'.

In some cases, cuttings taken close to the ground are more likely to root than those taken higher on the plant, since they tend toward an immature phase termed "physiological juvenility."

Longer shoots may be sectioned into several cuttings, but there may be some variation in root formation on cuttings taken from different parts of the same shoot. In the case of hardwood cuttings, the lower parts of the shoots root better than the tips; with softwood cuttings, the new growth of the tip generally roots more satisfactorily.

For some unknown reason, cuttings taken from plants growing in a greenhouse will frequently root successfully while comparable material taken from out-of-doors does not.

Physiological Juvenility

As young seedlings, plants go through an immature phase called "juvenility." Characteristics of young seedlings often differ from those found later in the plant's life. Cuttings of many plants that are difficult or impossible to root in the mature phase root easily in the juvenile phase.

In some instances, the change from juvenility to maturity fails to take place and the juvenile characteristics remain. Such plants have been called "fixed juveniles," and they root as easily as do seedlings of the same species regardless of age.

Procedure for Taking Cuttings

An effort should be made to gather softwood cuttings early in the morning before much transpiration has taken place and while they are in their freshest, most turgid condition. Hardwood cuttings may be taken any time of the day.

Cuttings should be removed from the parent plant with a clean sharp tool. The cut should be immediately above a bud, leaving no stub.

Cutting size is dependent on the growth rate of the plant that is to be propagated. Some gymnosperm cultivars produce less than ½ inch of growth in a single year so that, unless the stock plant is to be destroyed, only small cuttings can be taken. At the Arnold Arboretum, large cuttings consisting of two or three years' growth are usually preferred. Not only do they contain greater food resources, which lead to quicker rooting and more extensive root systems, but

Collected cuttings placed in a plastic bag bound at the mouth with a rubber band. Air remains inside so bags can be piled on one another without crushing contents. Photo: P. Chvany.

Portion of cutting that will be in rooting medium must be stripped clean of leaves and twigs. Photo: P. Chvany.

they produce plants of usable size more rapidly. Immediately upon collection, cuttings are placed in a polyethylene bag tightly sealed with a rubber band to prevent drying. Air is not squeezed out of the bags when cuttings are taken, since it provides a cushion that allows the bags to be placed on top of each other without crushing the contents. To prevent build-up of heat within the bags, they are shielded from the sun. A large capacity styrofoam picnic cooler may be used to protect freshly collected softwood cuttings.

After collection, the bags of cuttings are placed in a refrigerator to retain freshness until processed. It is best to handle all cuttings (particularly softwood) as soon as possible.

Processing of Cuttings

Cuttings are prepared for insertion by removing all twigs and leaves from the portion of the stem that will be in the propagating medium. If allowed to remain, this material may decompose, inviting infection from pathogenic organisms.

Removal of these parts also creates small wounds on the cutting. These wounds remove a physical barrier to root emergence, exposing a larger area to the action of root-inducing substances and en-

Cuttings of Taxus *showing various sizes. All will root, but heavier cuts on right tend to root faster and will produce usable plants sooner. Photo: P. Chvany.*

couraging formation of a more extensive root system. Frequently, wounding stimulates the development of protective tissue called callus, which is composed of undifferentiated cells. Callusing may precede rooting but is independent of it.

Cuttings are usually treated with root-inducing materials. Indolbutyric Acid (IBA) has proven satisfactory and is used extensively. Naphthalene-acetic acid (NAA), indoleacetic acid (IAA), and 2, 4, 5-trichlorophenoxy alpha propionic acid (2,4,5-TP), also are used. All but the last are commercially available in a number of different preparations, including combinations. IBA and NAA combined lead to excellent rooting response in certain cases. A fungicide added to the material also improves rooting, a synergistic effect not yet explained by plant physiologists.

Root-inducing substances are available in different concentrations. In general, the more difficult a taxon is to root, the higher the required concentration. For example, certain yew and arborvitae, and creeping juniper root well when treated with a powder formulation containing 3 mg IBA/gm of talc. More difficult taxa respond better to a concentration of 8 mg/gm of talc.

Root-inducing powder is applied to the basal parts of cuttings by dipping them into enough powder to coat the newly cut surfaces, then tapping them to remove any surplus. The cut surfaces are generally moist enough so that the rooting powder will adhere and wetting is unnecessary. It is advisable to estimate the amount of rooting material needed and transfer it to a separate container, discarding what is left after treatment, since dipping cuttings directly into the main supply moistens and contaminates it.

Liquid formulations of rooting materials are purchased in concentrations that can be diluted with tap water. Only enough solution should be prepared for the work at hand, since it too becomes contaminated when cuttings are dipped into it.

Rooting Medium

The rooting medium performs three functions. It holds the cutting in place, serves as a reservoir for water, and allows air to reach the cutting base. Sand, peatmoss, sphagnum moss, vermiculite, and perlite, among other things, are used as propagating media, frequently in combination. Any medium should be free of extraneous organic matter, such as dead leaves and twigs, that may introduce pathogenic organisms.

At the Arnold Arboretum, a one-to-one mixture of coarse sand and horticultural grade perlite is used for conifers. Perlite improves the physical structure of the medium, preventing compaction of fine particles of sand and allowing the removal of cuttings with less possibility of root damage.

When dealing with extremely small cuttings, such as those often taken from dwarf conifers, a mixture of sand and peatmoss sifted is substituted for the sand and perlite mix.

Root initiation is hastened by supplemental heat in the rooting medium. Thermostatically controlled electric heating cables buried below the root zone can be set at optimum temperatures for the cuttings being rooted. At the Arnold Arboretum, bottom heat is maintained at 75° F.

The depth to which cuttings are inserted depends to a certain extent upon the size of the cutting. The bases of large cuttings may be as much as 3/8 inch in diameter and will require insertion to a depth of 2 inches or more for adequate support. Smaller cuttings may be inserted more shallowly.

Before inserting cuttings, a hole is made in the rooting medium large enough to accept the cuttings without brushing off the rooting compound. For large numbers of cuttings, a single long slit can be formed by drawing a thick knife through the medium using a straightedge as a guide (metal instruments are less likely to carry infection than wooden ones.)

It is important that the cuttings be uncrowded in the bench. Enough space should be left between them to allow for free air circulation. Light should be allowed to reach the surface of the rooting medium to discourage the growth of harmful organisms.

Labeling is necessary to prevent confusion. Plastic labels are sanitary, can be marked with a graphite pencil, and remain legible for several years.

Cuttings should be arranged systematically in the medium. One method is as print runs in a book: starting on the left, cuttings are inserted in a line from front to back. When one line of cuttings is completed, the next begins in front again. A label precedes each lot of cuttings.

Once planted, the cuttings are heavily watered to compact the medium around them.

Propagating Structures for Cuttings

At the Arnold Arboretum, hardwood cuttings are propagated in winter either in open greenhouse benches or under polyethylene plastic, which maintains an atmosphere of high humidity. The benches, peninsular in design, are 6 by 5 feet wide, and 6 inches deep. They are constructed of ¾-inch transite. Each is completely lined with two-mil polyethylene plastic and 1½ inches of rooting medium is placed in the bottom. Heating cables are installed at this level and cover with ½-inch mesh hardware cloth. This promotes even distribution of heat by conducting it away from the cables.

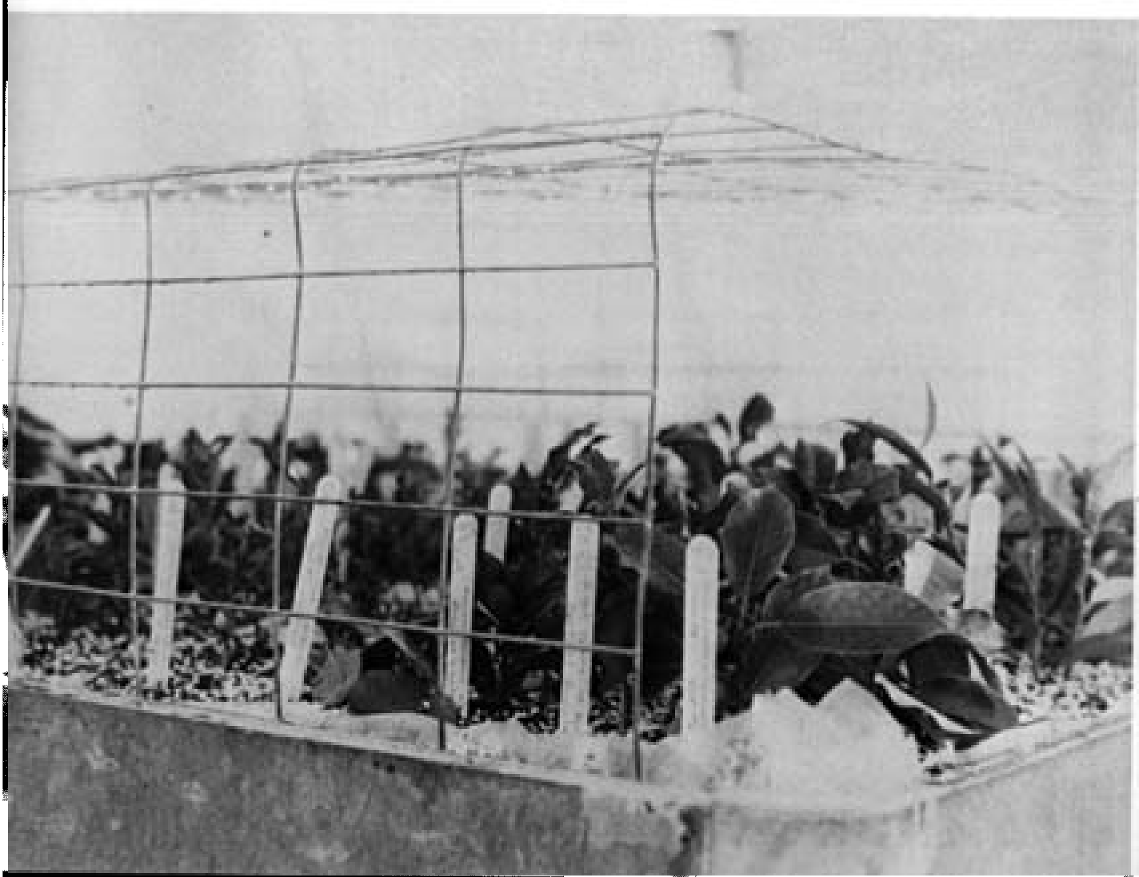
The polyethylene plastic covering over the bench is supported by a frame of 2- by 4-inch welded-joint wire mesh. This is known as turkey or utility wire and is obtained at farm supply stores. Purchased by the roll, it can be cut and bent into any shape. The frames are fashioned to hold the plastic about 10 inches above the rooting medium.

It is important that this framework lie flat on the top, rather than in a curve as is sometimes suggested. Temperatures within the propagating unit are warmer than the surrounding atmosphere and water continually condenses on the inner surface, accumulating in heavy droplets. These fall on the cuttings and into the medium, creating an environment of continual moisture. A flat surface above permits even distribution of the falling drops, whereas a curved top directs them to the sidewalls and down, leaving the center portion of the cutting bed dry.

In recent years elaborate mist systems have been employed for the propagation of softwood cuttings, preventing the cuttings from desiccating even in full sunlight. However, both hard- and softwood cuttings can be rooted satisfactorily in polyethylene enclosures. At the Arnold Arboretum, fall and winter cuttings still are rooted either in these structures or on an open bench even though mist systems were installed in 1962.

The chambers have some distinct advantages for amateurs. They are inexpensive and relatively carefree. There is little chance of loss through mechanical or human failure. Nutrients do not leach from the leaves as can happen under mist when cuttings require a long period to root. In areas where hard water presents a problem, there is no build-up of minerals on the cuttings.

Small numbers of cuttings can be rooted by amateurs in far less elaborate (but equally satisfactory) structures than those used at the Arnold Arboretum. A simple polyethylene bag, filled with root-



ing medium and placed in a container to give it support, is quite adequate for the rooting of most cuttings. Once the cuttings are inserted and watered-in, the bag should be bound at the mouth with a rubber band. This little propagating unit can be placed on a north window sill where cuttings will not be exposed to direct sunlight. It is important that the bag be set inside the container rather than the other way around, for water condensing on the bag's sides then can run back into the rooting medium.

A simple enclosure for outdoor propagation can be constructed for softwood cuttings. First, a site is chosen that offers as much light as possible without direct sunlight. (A location open to the sky and on the north side of a house, wall, or tree would be ideal.) A standard 1- by 2-foot greenhouse flat is pressed against the earth to show its outline, and the soil is then excavated to a depth whereby the flat's edges will be level with the surrounding soil. Two-mil polyethylene plastic is cut to line the flat with enough surplus so that it extends about 6 inches on all sides. A shallow excavation in the ground, framed with boards and lined with plastic to keep the surrounding soil from contaminating the rooting medium, could also serve as a container.

Medium is added to the container, slightly firmed, and the cuttings are inserted and watered. A flat-topped turkey wire frame, cut and bent to support the polyethylene plastic about 6 inches above cuttings, is placed over the container. The frame is covered with polyethylene and soil mounded over the plastic where it meets the ground to form a seal.

After-care of Cuttings

On cloudy, humid days, polyethylene coverings are removed and the cases checked for fallen leaves and dead cuttings which, if allowed to remain, would decay and invite disease. Cuttings should be checked weekly for symptoms of fungus and, if necessary, sprayed with a fungicide. Watering is seldom required.

After several weeks, the first signs of rooting may be observed. Cuttings may be checked by giving them a gentle tug. Heavy resistance indicates good roots; slight resistance, small roots; and no resistance, no roots. Occasionally, a ball of callus tissue forms at the base of cuttings but even after an extended period no roots appear. This tissue may be removed, the cuttings retreated with root-inducing material, and returned to the propagating chamber for a second try.

Once cuttings are rooted, they should be carefully lifted from the medium and potted or flatted in a suitable growing medium. Material rooted under conditions of high humidity and temperature must

Above left: A hole is made in the medium to prevent root inducing material from being rubbed away when cutting is inserted. Photo: P. Chvany.

Below: Section of propagating structure showing labelling arrangement and framework of 2- × 4-inch welded joint wire used to support polyethylene plastic film. Photo: P. Chvany.

be brought into normal atmosphere gradually. This is done by again covering them with polyethylene.

On cloudy, humid days the plastic can be removed; if several such days occur in succession, the transition will be complete. Otherwise, the cuttings may be uncovered at night and recovered during the heat of the day for a period of five or six days.

Layering

Layering is a simple but highly effective technique by which plants may be reproduced. It is perhaps the easiest of the asexual methods for amateurs to practice. Plants propagated by cuttings require special equipment to maintain a humid atmosphere so that excess water is not lost to the air. Layers remain attached to the parent plant and are sustained by it until sufficient roots have formed to make them self-sustaining. Water lost by transpiration from the leaves of branches being layered is replaced by the roots of the parent plant. As no facilities are needed for layering, it is the ideal method for amateurs who wish to propagate a few plants in their yards.

Layering of trees and shrubs can be done wherever the soil is workable.

Common or Simple Layering

The only type of layering suited to gymnosperm propagation is common or simple layering. Branches selected for common layering should be limber enough to be bent to the ground. Each branch is first arched to the ground and a line is scratched parallel to it and about a foot behind the branch tip. This scratch mark is used as a guide for digging a trench parallel to the bent branch and sufficiently deep to cover it.

The branch is fitted into the trench in such a manner that the tip can be bent into a vertical position. At the point where the branch turns sharply upward, it is girdled by cutting two parallel rings about ½ to 1 inch apart through the bark and around the branch. (This creates a block that intercepts the downward movement of auxins and other materials manufactured by the leaves and buds. A bulge forms above the girdle as these substances collect, and rooting is initiated at the swollen area.) The bark between the cuts is removed and the branch returned to the trench and pegged immediately behind the girdle with a heavy stone or a large staple made from a coat hanger or a forked branch. The tip of the branch above the girdle is then raised to an upright position with the girdle remaining at the lowest point in the bend. The trench is filled with soil and the branch tip staked to keep it vertical.

In the event the soil is poor at the layering site, a good, well-drained soil mix should be substituted in the trench when it is refilled. During periods of dryness, the soil in the area of the layer should not be allowed to dry out.

By carefully removing some of the soil covering the layer, it is possible to check the extent of root development. If adequate roots have formed in one growing season, the layer can be severed from the parent plant and moved to its new location. Some plants may require two growing seasons to form enough roots to sustain themselves. After being separated from the parent plant some conifers will require staking for several years in order to encourage upright growth.

Grafting

Grafting is the process of joining roots of one plant to the shoot of another so that they unite, grow, and function as a unit. The root portion of a graft is called the "rootstock" or "understock," and the shoot portion is termed the "scion."

Grafting requires time, skill, and special after-care, making it the most expensive method used to reproduce plants. When plants fail to produce seed or will not come true from seed, when they refuse to root from cuttings and are impractical to layer, they are grafted. In the past, many gymnosperms were grafted as a last resort because they did not come true from seed and were difficult to root. Advances in cutting propagation, such as the use of rooting compounds, mist units, and polyethylene enclosures, have made grafting less important in conifer propagation. A number of taxa that were grafted previously now can be rooted as routine practice.

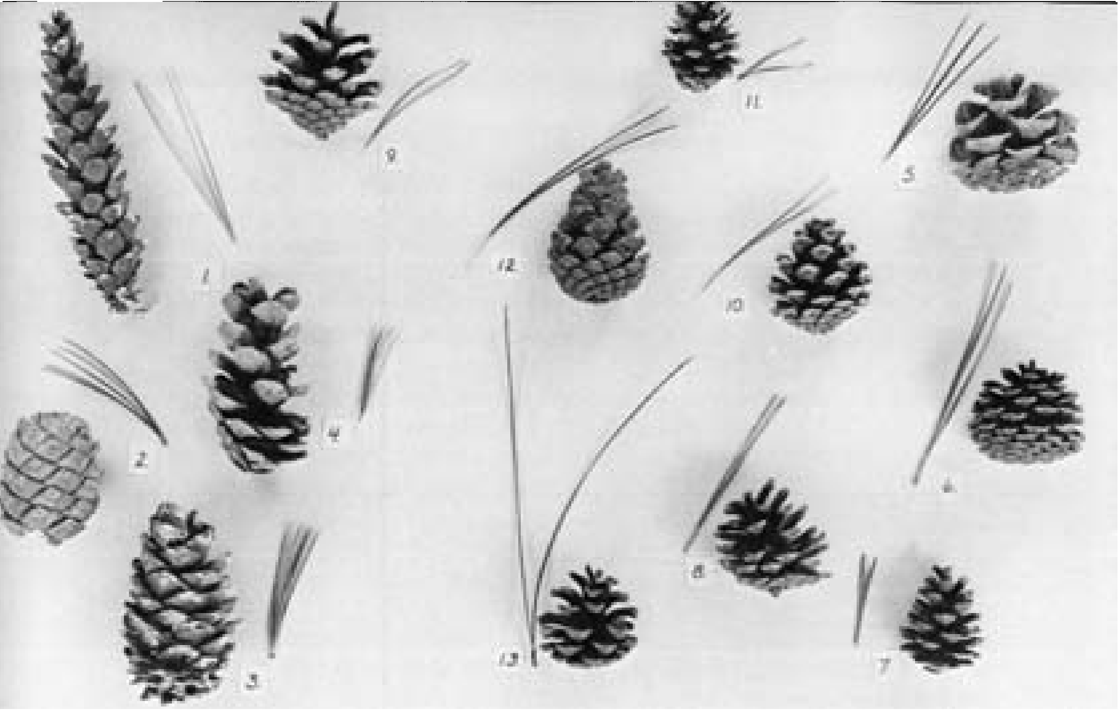
Compatibility

The most important factor in establishing a successful graft union is compatibility between rootstock and scion. When two species are incompatible, the rootstock and scion may fail to form connecting tissue that knits them together into a strong union. Movement of water and nutrients between rootstock and scion is partially or wholly restricted and the plant fails.

Many incompatible grafts fail immediately, the young plant never commencing growth following grafting. Others appear to grow for a period of weeks, months, or even years before failing.

The direct evidence of incompatibility may be abnormalities such as swellings at the graft union. The weak junction between stock and scion is susceptible to breakage, sometimes splitting cleanly apart in a wind storm, even after years of apparently normal growth.

In general, the more closely related botanically the two taxa are, the more likely they are to form a successful graft union. Grafting a variety on its species is almost always successful, but compatibility between species in a genus is highly variable. Though there is no reliable test for predicting incompatible combinations, trial and error have resulted in a number of recognized compatible combinations used commonly by nurserymen.



1. Pinus strobus, *2.* P. cembra, *3.* P. flexilis, *4.* P. parviflora, *5.* P. bungeana, *6.* P. rigida, *7.* P. virginiana, *8.* P. thunbergii, *9.* P. sylvestris, *10.* P. densiflora, *11.* P. banksiana, *12.* P. nigra, *13.* P. resinosa.

Selection and Storage of Scions

Gymnosperms are grafted in winter or early spring. Scions for grafting are collected late in the fall, after the plants have gone dormant and the buds have been exposed to a cold period. Only healthy wood of normal growth should be chosen. Shoots with long internodes that have grown rapidly make poor scion material. Wood with abnormalities of any kind should be rejected (unless the purpose of propagation is an attempt to reproduce the abnormality). Healthy, well-developed, vegetative buds should be present on the scion wood. Terminal growths of tree forms should be taken whenever possible, as the grafted plants require less training to produce normal, upright trees.

After collection, scion wood must be carefully stored to prevent desiccation of the wood and development of the buds. When a refrigerator is available, scions can be stored in sealed polyethylene bags at about 40° F. Alternatively, they can be stored in a box of slightly dampened sphagnum moss, peatmoss, or sawdust in a cool location. Excess moisture will cause deterioration.

All scions in storage should be distinctly labeled.

Selection and Preparation of Rootstocks

Both seedlings and rooted cuttings may be used as rootstocks for gymnosperm propagation. Cuttings of easily rooted taxa are used for those clones of false-cypress, juniper, yew, and arbovitae that are not easily rooted themselves. Seedling rootstocks are least expensive to produce, but they require more time to reach a usable size than do rooted cuttings. Rootstocks must be of a species compatible with the scion, and are best potted one growing season ahead of grafting so that a firm rootball will develop. Such understocks prepared in advance are called "established understocks." After potting, seedling understocks are plunged in an outside frame during the summer for storage and growth. In early winter, after they have been dormant long enough to satisfy cold requirements, they are brought into the greenhouse to be forced into active growth in preparation for grafting.

Rootstocks can be grafted as soon as they break dormancy and begin growth — usually three to four weeks after being placed in the greenhouse. They need not have begun topgrowth. If the root-tips show new growth, the plant is ready for grafting. At the Arnold Arboretum, most gymnosperms are grafted in January and February.

Tools

Two pieces of equipment, a knife and suitable tying material, are needed for grafting. The knife should be well-made of a high-quality steel. Good knives have folding or fixed blades, usually beveled on only one side. The blade is straight, about 3 inches long, and firmly hafted deep in a handle that fits comfortably into the user's hand.

The tying material can be grafting tape, grafting thread, or rubber strips that are used as wrapping to hold scion and understock together until the two unite. At the Arnold Arboretum, $\frac{3}{16}$-inch-wide strips of rubber, made especially for grafting or budding work and available commercially, are wound around the union from bottom to top. These are secured by slipping the end of the rubber strip under the last turn taken. An ordinary cut rubber band also would be satisfactory. If exposed to sun and air, it rots away. Below ground, the rubber does not deteriorate and can girdle small plants if not removed.

Wax is not used for conifer grafting, since natural resins seal the graft union, preventing desiccation.

Grafting Techniques

A successful graft union depends on new cells formed by the scion and rootstock that mingle and interlock. These cells originate from a ring of tissue just under the bark of rootstock and scion called the "cambium layer." The cells form callus tissue which eventually gives rise to new cambial and vascular tissue, forming a completed graft union.

To insure a graft union, it is important that the cambial layers of stock and scion be placed against each other in such a manner that callus formation is promoted. (Cambium layers are usually green, sometimes red, and are easily exposed by a cross-section cut through scion and rootstock.) All grafting techniques are designed to allow close cambial contact. Only the side graft, the veneer graft, and the whip-and-tongue graft are customarily used in grafting gymnosperms.

Side Graft

To prepare the stock plant for side grafting, branches are removed from the stem for several inches above the soil line. The side with the least knots and blemishes is selected and a shallow downward cut about 1½ inches long is made through the bark and cambium and into the wood to form a small tongue. The scion is then prepared by removing two slivers of different sizes from either side of its base. To complete the graft union, the scion is fitted to the understock so that the cambial surfaces are united and the tongue covers the outer cut. Care must be taken to match as much cambial surface as possible. If the understock is larger than the scion, fitting should be done so that the cambium layers are in contact at the bottom and along one side. The combination now is ready for binding with a rubber budding strip. Top growth remains on the understock of the grafted plant until the scion has come into growth; it then can be removed in either one or two stages depending on the subject being propagated.

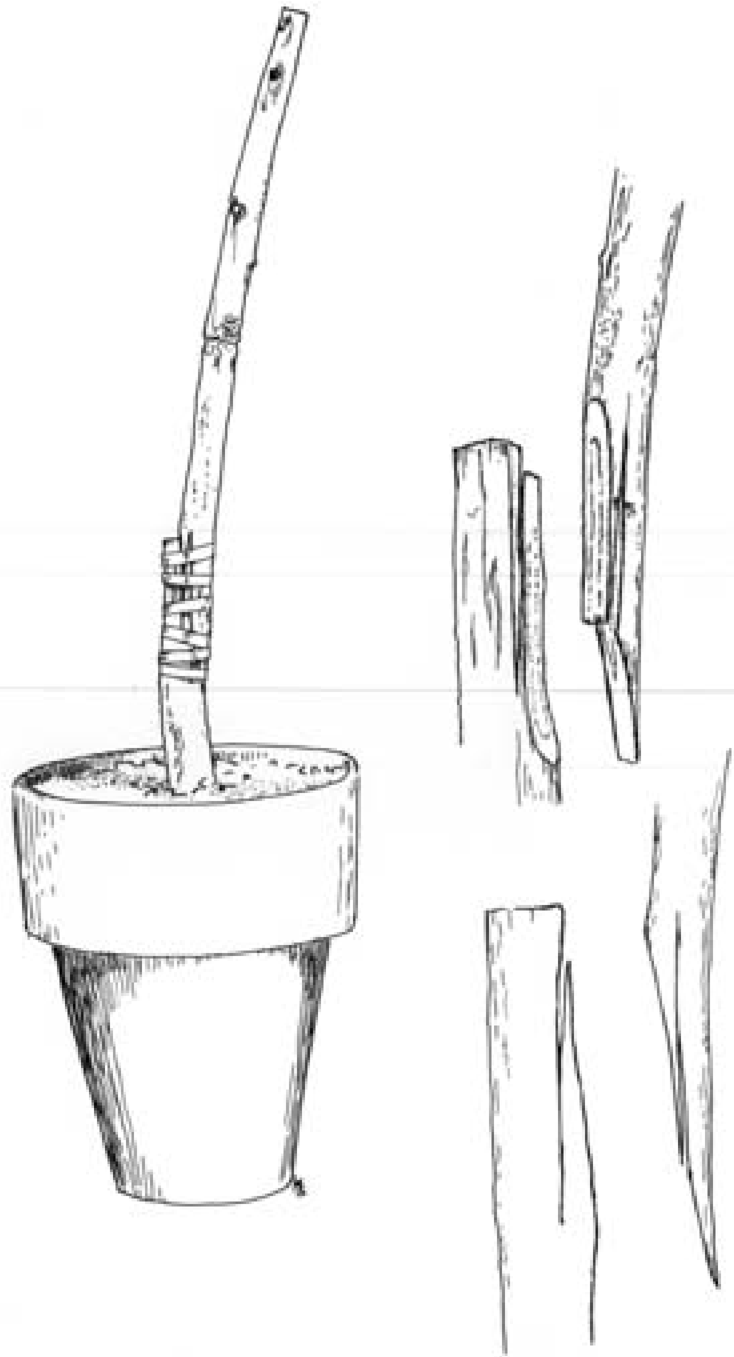
Veneer Graft

This is a widely used variation of side grafting. The stock plant is prepared by removing a piece of bark and wood from the area just above the soil line with two cuts. One cut, downward and slightly inward, is about 1½ inches long. The second cut is short, downward and inward, about three-quarters of the way down the first cut and intersecting it. A short spur of bark and wood is left at the base of the long cut.

The scion is also prepared with two cuts — a long shallow one on one side of its base and a short slanting one on the opposite side. It is then fitted into the rootstock, cambium layers carefully matched, and the union bound with a rubber strip. As with the side graft, the top growth remains on veneer-grafted plants until the scion begins active growth.

Veneer Graft. Drawing: M. Givens.

Side Graft. Drawing: M. Givens.



Whip-and-Tongue Graft. Drawing: M. Givens.

Whip-and-tongue Graft

This is the only grafting technique used for gymnosperms in which the top growth of the stock plant is entirely removed prior to grafting. A sloping cut is made through the stem after the top growth is removed. A second, downward vertical cut is made through the surface exposed by the first cut, forming a small tongue of wood.

To prepare the scion, a long sloping cut is made at its base, the same length as the first cut on the stock plant. A second cut is made through the first, forming a thin tongue similar in size to that of the stock plant. To form the graft the tongues of stock and scion are tightly fitted together so that they are immovable. They should be joined with as much cambial contact as possible. When a scion of small diameter is grafted on a larger understock, care should be taken that the cambium layers meet on at least one side. The completed graft is bound with a rubber band.

After-care of Grafts

Following grafting, plants are plunged in a greenhouse bench with bottom heat. This encourages the development of callus tissue, the first step in the formation of a graft union. The graft union should be completely covered with dampened peatmoss to prevent desiccation as the cut tissue knits.

As callus tissue forms and growth activity begins to appear on the scion, the top growth of the understock, if it remains, may be reduced. This is usually done in two steps, half the top growth being removed first, the remainder at a later date, when growth of the scion is well advanced.

In the spring, after danger of frost is past, young grafted plants can be planted outside. They should be placed with the graft union below the surface of the soil to encourage formation of roots on the scion. Before placing them outside, the grafting rubbers must be removed, since they will not deteriorate beneath the ground.

Budding

Budding is a form of grafting that makes use of a single vegetative bud as a scion. Large numbers of plants can be budded quickly and efficiently, a smaller quantity of scion stock material is required than would be needed for grafting, and no special facilities are needed.

Budding is done when the stock is growing actively, its bark can be separated easily from the wood, and the scion buds are well-developed.

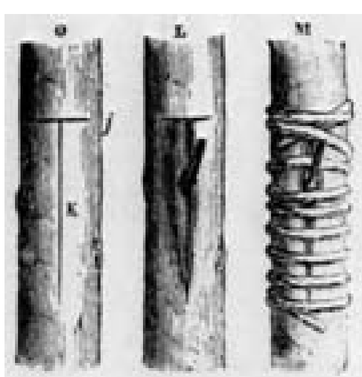
To prepare for summer budding, shoots of the current season's growth are cut. To reduce transpiration, the soft tip and leaf blades are removed. About ½ inch of the petiole is allowed to remain to serve as a handle when processing the buds. At this stage the shoot is termed a bud stick. Bud sticks must be kept in fresh condition until ready for use. When stored in a cool place in sealed polyethylene bags they will keep in good condition for a week or more.

The most common budding technique is shield or T-budding. These names are derived from the shield-like appearance of the prepared scion and the T-shaped cut that is made in the stock plant.

To remove the bud scion from its stick, a cut is made from about ½ inch below the bud to about ½ inch above it, forming a small oval shield. The shield should be thin but not too flexible. Some propagators recommend removing the sliver of wood attached to the shield behind the bud. At the Arnold Arboretum, however, this is allowed to remain, since its removal may damage the bud or leave an air space immediately behind where it is joined by the rootstock

To insert the bud in the rootstock, a T-shaped incision is made through bark and cambium to the woody layer beneath. The flaps of bark thus formed are raised from the wood and the bud shield slipped between them and forced downwards into the slit. The bud should be positioned well below the horizontal cut, so that the flaps may be closed above it. To hold the bud in place, commercially available rubber budding strips or plastic bud ties are wrapped above and below it. In about a week, success or failure can be determined. If the portion of petiole accompanying the bud falls away when tapped, the bud has taken; if it is shrivelled and attached, failure is indicated and a second attempt can be made by inserting another bud in a different location.

Examination in early spring will reveal whether or not the bud is still alive. If so, the understock is cut away about ½ inch above the bud. An occasional inspection after growth begins will reveal whether sprouts are developing on the stock beneath the bud. These can be removed quickly by hand rubbing while they are still soft.



Shield budding showing T-shaped incision, inserted bud, and twine binding. From Charles Baltet, L'Art de Greffer. *Paris. 1885.*

GENERA

ABIES: **Fir**

There are about forty species of fir native to the Northern Hemisphere. They are evergreen trees of pyramidal habit. Except for their cultivars, fir trees are commonly propagated by seed.

Sexual Propagation

Male and female cones of *Abies* are borne on the same tree. The oblong female cones stand erect on branches of the previous year's growth and are composed of thin, closely spaced scales, each having two seeds at its base. Cones ripen in autumn of their first year and shatter from the top down, releasing winged seeds to wind dispersal. Since the cones shatter shortly after they mature, they should be collected as soon as possible after ripening. They are attached to the tree by short woody stalks and must be cut free. After the cones dry, seeds may be separated from the scales by screening and fanning techniques.

Fir seed loses viability in less than a year if kept in dry storage. To assure high percentage of germination, it should be sealed and placed in controlled cold storage until time for stratification. *Abies* seed exhibits embryo dormancy, which can be overcome by two or three months of cold stratification at 40° F. Because the seedlings are particularly susceptible to damping-off organisms, pretreatment should be planned to coincide with the lengthening days of late winter or early spring. If stratification is extended beyond the three-month period, the seeds tend to germinate in the cold. Depending on the species and seed lot, germination takes from one to three weeks.

Asexual Propagation

Cutting

At the Arnold Arboretum, cuttings of some abnormal *Abies* cultivars have rooted in high percentages. When treated with a rooting compound containing 3 mg IBA and 150 mg Thiram (a fungicide) per gram of talc, three out of four cuttings of *Abies koreana* 'Prostrate Beauty', taken in June were rooted. *Abies balsamea* 'Nana' cuttings taken in December rooted almost as well when treated with a rooting compound containing 8 mg IBA per gram of talc, plus a fungicide.

Grafting

Choice of understocks for the grafting of fir trees is less limited than for many genera. *Abies alba* and *A. balsamea* are generally considered suitable understocks for all *Abies* clones. *Abies nordmanniana* is compatible with most short-needled firs, and *A. concolor* with those having long needles.

Scions taken in January and February are side-grafted on established understocks potted one growing season in advance of their use. The plants are then plunged in peatmoss to a depth that covers the graft union.

These graft combinations have survived a significant number of years at the Arnold Arboretum.

Rootstock	Compatible Scion
Abies balsamea	*Abies alba*
	A. amabilis
	A. cilicica
	A. fargesii
	A. fraseri 'Prostrata'
	A. lasiocarpa 'Compacta'
	A. procera 'Glauca'
	A. veitchii
	A. veitchii var. *olivacea*
A. concolor	*A. cephalonica*
	A. concolor 'Violacea'
A. firma	*A. alba*
	A. concolor 'Conica'
	A. concolor 'Violacea'
	A. firma
	A. homolepis
	A. koreana
	A. lasiocarpa 'Compacta'

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U.S.D.A. Forest Service. Seeds of Woody Plants in the United States. Agric. Handbook No. 450. Washington. 1974. pp. 168–183.

ACTINOSTROBUS: Actinostrobus

This genus contains two species of shrubs. They are related to *Callitris* and are native to Western Australia. The unopened cones of these evergreens remain on the plants for a long period. They may be picked and allowed to dry, after which the scales will open, releasing the seed. Seed germinates readily without special treatment. Cuttings should be taken from the tips of vigorously growing twigs. Mist is recommended, or the bench may be covered with a polyethylene propagating structure. Without hormone treatment, rooting takes six to nine months.

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AGATHIS: Kauri Pine

Sixteen to twenty species of large evergreen trees with massive trunks make up this genus, which is native from the Malay Peninsula to New Zealand. There is little information on propagation. Seed appears to germinate readily, but must be sown immediately upon collection. Many of the seeds are infertile. Adventitious shoots from the stumps of felled trees exhibit physiological juvenility and may be used as cuttings.

As with *Actinostrobus*, cuttings should be taken from the tips of vigorously growing twigs. They should be rooted under mist or polyethylene plastic. In the absence of hormone treatment, rooting takes six to nine months.

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ARAUCARIA: **Araucaria**

There are ten or twelve species of *Araucaria*, some natives of South America, others of Australia and the Pacific Islands. These plants are most commonly propagated by sexual means.

Sexual Propagation

Male and female cones of *Araucaria* are borne on the same tree. The female cone is ovoid and composed of wedge-shaped scales that break apart at maturity to release winged seeds. The seed is produced at irregular intervals and much of it is infertile. It deteriorates quickly and should be sown immediately upon collection. Germination is usually good, but growth of seedlings is slow.

Vegetative Propagation

Rooted cuttings of *Araucaria heterophylla* develop into more desirable trees than do seedlings, as they are slower growing and more compact in habit. Only vertical shoots, however, are suitable for cuttings; shoots from branches root, but they lead to misshapen plants. Though *Araucaria* ordinarily produces only one vertical shoot, its leader, it is possible to produce numerous suitable cuttings from one stock plant. A seedling is grown until it has five or six branch whorls, and its leader is removed and rooted. Erect shoots soon arise from the axils at the top whorl of branches and can be removed and rooted. The plant is then cut back to the next whorl of branches, where a second set of vertical shoots develops. This process may be continued until shoots have been taken from the axils of the last whorl of branches.

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U.S.D.A. Forest Service. Seeds of Woody Plants in the United States. Agric. Handbook No. 450. Washington. 1974. pp. 223–225.

ATHROTAXIS: **Tasmanian Cedar**

This genus of three evergreen trees, native to the mountains of Tasmania, is apparently related to *Cryptomeria. Athrotaxis* species are commonly propagated by both seeds and cuttings. Seeds should be sown in February or March. Cuttings should be taken in late spring or early summer from the tips of vigorously growing twigs, and inserted in sandy soil under mist or in a polyethylene propagating structure.

Rooting, without hormone treatment, takes six to nine months. Cuttings of *Athrotaxis selaginoides* form callus readily, but root poorly. *Athrotaxis* has been grafted successfully on stocks of *Cryptomeria japonica.*

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AUSTROCEDRUS: **Austrocedrus**

This monotypic genus of variable sized trees often has been included in *Libocedrus* and is native to Western Argentina and Chile.

Austrocedrus chilensis. "Cuttings of ripened wood (brown at base) with heel inserted in 75% peat, 25% sand mixture, in mist unit with medium temperature of 65° — 75° F, rooted 50% successfully. Cuttings similarly treated in February were a total failure." D.M.H.

CALLITRIS: **Cypress Pine**

An evergreen genus of about twenty species of trees and shrubs, *Callitris* are native to Australia and Tasmania. They are best propagated from seed, which germinates readily. It is borne in a globular cone composed of six to eight woody scales arranged in one whorl. The cone remains on the tree for a long period and can be collected at any time. When dry, it opens to release the dark brown winged seeds. Many of the seeds are infertile.

Cuttings taken from the tips of vigorously growing twigs of *Callitris oblonga* and *C. tasmanica* have been rooted. Mist is recommended, or the propagating bench may be covered with plastic. Rooting without hormone treatment takes six to nine months.

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CALOCEDRUS: Incense-cedar

There are three species of evergreen trees in the genus *Calocedrus* native to North America (*C. decurrens*), Formosa (*C. formosana*) and China (*C. macrolepsis*) respectively. They were formerly included in the genus *Libocedrus* but probably are more closely related to *Thuja*.

Incense-cedar is best reproduced from seeds, though cutting and grafting propagation are possible.

Sexual Propagation

Male and female cones are borne separately at the tips of twigs on the same tree. Oblong, pendant female cones mature in one season, but remain attached to the branch until the following year. They are composed of six paired, hard flat scales. Each of the two middle scales bears two winged seeds which are shed in late summer and early fall. Crops are not produced regularly, but when they do occur they are heavy. The seeds have a broad wing and can be carried great distances by air currents. Cones are ready for collection when they turn a light reddish-brown. They can be separated from the seed by screening. Under ordinary storage conditions, seed loses viability rapidly, but storage of dry seed in sealed refrigerated containers prolongs its life somewhat. A fair percentage of incense-cedar seed germinates without pretreatment, but a two- to three-month period of cold stratification greatly improves and unifies germination.

Asexual Propagation

Partially hardened cuttings of *Calocedrus* may be taken in August. Scions consisting of the current year's growth can also be grafted at this time. A side graft should be used on understocks of *Thuja occidentalis* established at least one growing season ahead of their use.

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CEDRUS: Cedar

Members of this genus are found in North Africa and Asia. There are four species, all large evergreen trees. Cedars are generally propagated by seed.

Sexual Propagation

Male and female cones of *Cedrus* are borne on the same tree. The mature cones are large, light brown, and held upright on the tree branches by short woody stalks. They are composed of numerous thin woody scales, each with two seeds at its base. The seeds are roughly triangular in shape and have a broad papery wing that aids in wind dispersal when the cones shatter to release seeds in autumn of their second or third year. In the Northeast, cones are ripe enough for collection by August and are cut free from the branches before they crumble apart. After they dry, scales and seeds break away from the central woody axis and must be separated from each other. Since they are similar in size, screening is impractical. Small quantities of seed may be hand-cleaned, while large quantities must be separated from the scales by fanning techniques. The seed is fragile and must be handled gently. It need not be dewinged. *Cedrus* seeds lose their viability after several months if kept at room temperature, but seeds dried for a week or two, then placed in sealed polyethylene bags and stored in a refrigerator at 40° F have germinated in high percentages after two years.

Extremely variable degrees of dormancy may be observed within a single lot of *Cedrus* seeds. If they are not provided with a period of cold stratification, they germinate erratically over a period of several months. Seeds stratified for one month at 40° F germinate in about two weeks, while those stratified for two months germinate in four to seven days. After three months of stratification, germination takes place in the refrigerator. Because cedar seedlings are particularly susceptible to damping-off organisms, it is advisable to germinate them in the lengthening days of late winter or early spring. Dry seed should be placed in cold storage until about two months before the desired germination date, then treated to a period of cold stratification and sown.

Asexual Propagation

Cutting

Cedrus libani and *C. atlantica* cuttings have been rooted, but usually in small percentages. However, cuttings taken in October from some clones of *C. deodara* have rooted well. The table below shows four treatments which led to high rooting percentages in *Cedrus deodara* 'Kingsville'. Cuttings were placed under polyethylene film with bottom heat at 75° F. After one growing season, the rooted cuttings were 22 inches tall. *C. deodara* 'Kashmir' and an unnamed clone each showed similar responses.

Cedrus deodara 'Kingsville'

Treatment	Number of Cuttings	% of rooting
Powder Formulations		
8 mg IBA plus 150 mg Thiram per gm of talc	50	90
Liquid Formulations (5-second dip)		
5 mg IBA plus 5 mg NAA per gm	50	84
2.5 mg IBA plus 2.5 mg NAA per gm	50	64
10 mg IBA per gm	50	80
Control — no treatment	50	88

Grafting

Cedrus can be propagated by side-grafting seedling understocks in January or February, when roots begin active growth. The understocks are potted one growing season in advance of their use and provided with a cold period before being brought into the greenhouse. *Cedrus libani*, *C. atlantica* and *C. deodara* all are compatible and can be used as understocks, but *C. deodara* is preferred, since it has the most compact and fibrous root system.

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* This cultivar later was determined to be *Cedrus deodara* 'Kingsville'.

CEPHALOTAXUS: **Plum-yew**

All five species of *Cephalotaxus* are native to Asia. They are evergreen trees or shrubs and may be propagated by seeds or cuttings. Male and female cones of the genus are borne on separate trees. The fleshy cones are about 2½ centimeters long, each bearing one or two seeds. They ripen during their second season.

Softwood cuttings taken from the tips of *Cephalotaxus harringtonia* twigs in late June have been rooted under intermittent mist, after treatment with a powder formulation of 2, 4, 5-T and NAA. In five instances, cuttings taken in autumn and treated with 8 mg IBA in a gram of talc plus the fungicide Thiram have rooted in high percentages. Seeds stratified for three months at 40° F produced 70% germination in ten days.

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CHAMAECYPARIS: **False-cypress**

There are six species of false-cypress: three native to North America, three to East Asia. Since there are a large number of recognized cultivars, *Chamaecyparis* is usually propagated asexually.

Sexual Propagation

Male and female cones are borne separately on the same plant. The female cones are small and spherical, composed of six to twelve scales. They open in autumn of the first year to release from one to five winged seeds per scale for dispersal by the wind. The empty cones may remain on the tree through the winter. Seeds are small, slightly flattened and oblong, with two narrow longitudinal wings. When cones turn from yellow-green to pale brown, they are ready for collection and drying. Seeds can be separated from the dry cones by screening, but they are easily damaged and should not be dewinged. They lose their viability quickly unless stored in sealed containers at 40° F following collection.

Some species of *Chamaecyparis* exhibit embryo dormancy. There is also variation between different lots of the same species, with dormancy apparently influenced by the geographic origin of the seed. In all cases, a two- or three-month period of cold stratification is of benefit, leading to rapid germination and a uniform stand of seedlings. *Chamaecyparis* is particularly susceptible to damping-off and germination during the lengthening days of late winter or early spring increases chances of survival. If necessary, stratification can be extended beyond the three-month period so that the seeds can be sown in late winter or early spring.

Asexual Propagation

Cutting

Hardwood cuttings of most *Chamaecyparis* cultivars, taken any time from September to April, root in high percentages. Cuttings of normal size may be taken from most *Chamaecyparis*. However, some cultivars produce less than a ½ inch of growth in a single year and must be propagated from extremely small cuttings. Cuttings may be treated with a variety of commercially available rooting compounds. Preparations containing 3 mg IBA per gram of talc have been used. *Chamaecyparis pisifera, C. thyoides* and *C. lawsoniana* root in approximately three months. In an English experience, extending the day length by four hours with artificial lighting increased the speed and percentage of rooting.

In general, *Chamaecyparis obtusa* and *C. nootkatensis* cultivars are more difficult to root than those of other species. Cuttings taken in late winter or early spring appear to root more easily than those taken in fall or midwinter. Growth-promoting materials containing 8 mg IBA per gram of talc have been used for these hard-to-root taxa, and in recent years, materials containing combinations of IBA plus NAA have been used effectively. Rooting time for *Chamaecyparis obtusa* cultivars varies widely, and rooting percentages are sometimes low.

Grafting

Grafting has been an accepted way of propagating the more difficult-to-root taxa of *Chamaecyparis*. In the nursery trade, *C. obtusa, C. lawsoniana*, and *C. nootkatensis* are frequently grafted on *Thuja orientalis* or *Chamaecyparis lawsoniana* seedlings. Rooted cuttings of *Chamaecyparis pisifera* 'Boulevard' are also satisfactory understocks for these taxa. 'Boulevard' is a juvenile form and can be rooted easily. Cuttings inserted in October or November are ready for veneer- or side-grafting by January or February. After grafting, plants are plunged in peat to above the level of the graft union.

Chamaecyparis lawsoniana seedlings have also been used for special purposes such as the production of tall rootstocks for grafting standard plants.

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CRYPTOMERIA: Cryptomeria

Cryptomeria japonica, native to China and Japan, is the only species in this genus. *Cryptomeria* may be propagated by seed, which has a reputation for germinating poorly. A sowing rate based on 30% germination to obtain a proper seedling density has been reported from Japan. Sixty to ninety days of cold stratification at about 40° F is recommended.

Cultivars of *Cryptomeria* are usually propagated by grafting, using the species as understock. However, cuttings of many cultivars have rooted in high percentages. Among these are 'Bandai-Sugi', 'Compressa', 'Cristata', 'Elegans', 'Nana', 'Spiralis', 'Spiralis Falcata', and 'Vilmoriniana'. All were taken in autumn and propagated in polyethylene structures. Root inducing material containing 8 mg IBA per gram of talc plus the fungicide Thiram at the rate of 150 mg has proven satisfactory for rooting *Cryptomeria* cuttings.

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CUNNINGHAMIA: China-fir.

The genus *Cunninghamia* contains three species of evergreen trees related to *Taxodium* and *Sequoia* and native to China and Formosa. China-fir can be propagated by both seeds and cuttings. Male and female cones are borne on the same tree. The cones are round with leathery scales, each bearing three seeds. Following release of seeds, the cone persists on the tree. Hardwood cuttings taken in autumn and treated with 8 mg IBA plus a fungicide root in high percentages. However, they tend to retain the characteristics of a branch, resulting in horizontal growth.

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CUPRESSUS: **Cypress**

This is a genus of about twenty species. Cypress are widely distributed in the warmer areas of the Northern Hemisphere. The best known species, *Cupressus sempervirens*, is widespread in the Mediterranean region.

Cypress may be propagated by seeds, cuttings, and grafts.

Sexual Propagation

Male and female cones are borne on the same tree. Female cones, small and globe-like, ripen their second season and consist of six to twelve scales, each having numerous winged seeds. Many cones remain closed on the tree for long periods of time. They can be collected as soon as they turn dark brown; the seeds are separated by screening. Seeds can be held from one to four years with little loss of viability if refrigerated in sealed containers. A period of cold stratification, usually about two months, appears to improve germination.

Asexual Propagation

Cupressus cultivars can be increased by cuttings taken in July and August. *Cupressus macrocarpa* cuttings responded well to treatment with IBA prior to insertion. Although a number of authors recommend taking cuttings between October and February, we have not had much success (± 10%) at the Arnold Arboretum with cuttings taken at this period.

Scions from *Cupressus* cultivars can be veneer-grafted on two-year understocks of the parent species. Because the foliage is especially susceptible to mildew, an effort should be made to keep the foliage dry when caring for newly grafted plants.

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× *CUPRESSOCYPARIS:* Leland Cypress

× *Cupressocyparis leylandii* is an intergeneric hybrid between *Cupressus macrocarpa* and *Chamaecyparis nootkatensis* which originated spontaneously at Leighton Hall, Welshpool, England in 1888.

The propagation of × *Cupressocyparis* is similar to that of the easily propagated forms of *Chamaecyparis.* Cuttings taken in autumn and winter have rooted in high percentages when treated with 8 mg of IBA in a gram of talc combined with a fungicide.

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DACRYDIUM: Dacrydium

Dacrydium is a genus of about twenty species of evergreen trees related to *Podocarpus.* They are distributed from the Malay Peninsula and Indo-China south to Australia, Tasmania and New Zealand, and one species, *D. fonkii,* is native to Chile.

Dacrydium may be propagated by cuttings taken from the tips of vigorously growing twigs and rooted under mist or plastic. Without benefit of hormone treatment, root initiation takes from six to nine months.

Dacrydium cupressinum and *D. laxifolium*

"Heel cuttings, semi-ripe at various times during the summer, rooted between 35%–75% successfully. August/September appears to be the optimum period. A rooting medium of 75% peat/ 25% sand has been used. Similarly treated cuttings taken in December were a total failure." D.M.H.

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DISELMA: **Diselma**

A single species of evergreen bush, or small tree, related to *Fitzroya, Diselma archeri* is native to Tasmania.

Cuttings of this plant may be taken from the tips of vigorously growing twigs. Mist is recommended, or the bench may be covered with plastic. Rooting, without hormone treatment, takes six to nine months.

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EPHEDRA: **Ephedra**

A genus of about forty species of leafless shrubs, *Ephedra* is native in warm dry areas in both North America and Eurasia.

Seeds germinate readily without special treatment.

Cuttings are reputed to root readily. Layering seems to be common in nature.

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FITZROYA: **Fitzroya**

Fitzroya is a monotypic genus of large evergreen trees related to *Callitris*, and native to Chile and western Argentina. It can be propagated by seeds and cuttings, though it is reported that most cultivated trees bear only female cones and produce infertile seed.

"Cuttings of ripened wood (brown at base) with a heel, inserted in 75% peat/ 25% sand, under mist, with the medium at 65°–75° F, rooted 75% when taken in mid-August. Cuttings taken in mid-November were a total failure." D.M.H.

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GINKGO: Maidenhair Tree

Ginkgo is a monotypic genus unknown in the wild, but preserved for many years in the temple gardens of China. It is best propagated vegetatively as seedlings lead to plants that vary widely in growth rate and tree shape. Female plants are undesirable because of malodorous fruits. Therefore desirable clones are propagated asexually.

Sexual Propagation

Male and female reproductive structures are produced on separate trees. It takes twenty years or more for seedlings to develop their first cones and then the crops are not borne regularly. Some trees appear to be alternate bearers. The buff-colored seed, with a hard seedcoat, is enclosed within a fleshy pulp, and is mature in autumn of its first year. Its fleshy outer layer would suggest natural dispersal by birds or animals, but none is known to feed on it. Since the ginkgo (*Ginkgo biloba*) is a primitive tree, its vector quite possibly is extinct. For this reason, seeds are never carried far from the parent plant.

Ginkgo seed is ready for collection in autumn about the same time the tree's leaves begin to fall. Seed can be cleaned by maceration and flotation techniques; gloves and protective clothing are recommended since there have been reports of illness among workers processing ginkgo seeds. The seed loses viability quickly if stored at room temperatures. It should be placed in sealed containers and held at 40° F. to prolong viability. Newly collected ginkgo seed requires a period of after-ripening, since it shows no embryo. When sown out-of-doors immediately following collection, the seeds develop embryos and germinate in the spring. In one experience with seed germinated in the greenhouse, untreated seed germinated erratically over a period of eighty-one days. Seven tests using cold pretreatment for various periods, and tests combining warm and cold pretreatment failed to unify germination.

Asexual Propagation

Cutting

Ginkgo cuttings can be taken in late June from the current season's growth as the shoots become woody. When treated with a rooting compound containing 8 mg IBA and 15 mg Thiram per gram of talc, and placed either under mist or polyethylene plastic, rooting occurs in seven to eight weeks. Ginkgo trees have a rather unusual growth pattern. Terminal buds lead to long shoots while lateral spurs generally produce short shoots. Since long shoots are found mainly at the branch tips of ginkgo trees, it is difficult to obtain long cuttings in quantity. Experiments have shown that cuttings made from short lateral spurs will root as well as those made from long shoots. Rooted spurs produced long shoots their second summer after a period of dormancy. By their second autumn, the plants were about 2 feet tall.

Grafting and Budding

Ginkgo trees are frequently grafted by commercial nurserymen. Scions can be taken in January and February and grafted on potted understocks using a whip-and-tongue graft.

Ginkgo may be shield-budded during the growing season when the bark separates easily from the wood. This technique is used to propagate ginkgo standards. Buds, usually from the cultivar 'Pendula', are inserted high on a 6- to 8-foot standard rootstock.

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JUNIPERUS: **Juniper**

About sixty species of trees and shrubs, almost all native to the Northern Hemisphere, make up this evergreen genus. Junipers are commonly propagated both sexually and asexually.

Sexual Propagation

Male and female cones of *Juniperus* are borne on the same, or occasionally different, plants. The mature female cone is fleshy, containing from one to twelve brown seeds. Depending on the species, it is light or dark green. When ripened in autumn of its first, second or third year, it turns to blue, red-brown or black, with a distinct bloom. Cones should be collected as soon as possible after ripening, since they are taken quickly by the birds. *Juniperus ashei* and *J. virginiana* cones ripen in autumn of their first year; those of *J. occidentalis*, *J. deppreana*, *J. scopulorum*, *J. osteosperma*, *J. recurva* and *J. rigida* in autumn of their second year; and those of *J. communis* and *J. monosperma* in autumn of their third year following pollination. *Juniperus sabina* ripens in fall of the first season or spring of the second. Seed may be cleaned by macerating the cones in a modified blender and floating the pulp and void seeds away.

All juniper seeds exhibit embryo dormancy and require a three-month period of cold stratification to induce germination. Many benefit from at least a five-month period of warm stratification prior to cold stratification in order to overcome impermeable seed coats.

Asexual Propagation

Cutting

Junipers exhibit extremely variable rooting behavior, depending on the species. *Juniperus communis, J. conferta, J. horizontalis* and *J. sabina* are easily rooted from cuttings taken in October, November or December. Summer cuttings may be rooted if taken back to mature wood of the previous year's growth. Root-inducing materials are not necessary, though treatment with a compound containing 3 mg IBA per gram of talc may hasten root initiation and encourage more extensive root development. Cuttings root in eight to ten weeks.

Juniperus procumbens, J. pseudosabina, J. recurva and *J. squamata*, and most of their cultivars, root in worthwhile percentages. Cuttings taken in November and December have responded well when treated with a material containing 8 mg IBA per gram of talc and wounded on one side. Rooting occurs in about three months.

In one experience, cuttings of *Juniperus distans*, taken in November and treated with a compound containing 8 mg IBA per gram of talc, rooted in four months.

Some of the variants of *Juniperus chinensis* are grafted, but many can be rooted successfully. *Juniperus chinensis* 'Hetzii' roots so easily that it is frequently used as an understock for other junipers. Cuttings may be taken in autumn and treated with a rooting material containing 3 mg IBA per gram of talc. More difficult-to-root cultivars may be treated with a material containing 8 mg per gram of talc. Rooting occurs in three to four months.

The following cultivars of *Juniperus chinensis* have been rooted commercially: 'Armstrongii', 'Blue Cloud', 'Columnaris', 'Fairview', 'Globosa Cinerea', 'Hetzii', 'Kaizuka', 'Kalley', 'Keteleeri', 'Obelisk', 'Old Gold', 'Olympia', 'Pfitzeriana Aurea', 'Pfitzeriana Compacta', 'Pfitzeriana Glauca', 'Plumosa Aurea', 'Pyramidalis', 'Richeson', 'San Jose', 'Shoosmith', var sargentii, var. sargentii 'Glauca', 'Spartan', 'Variegata'.

Juniperus virginiana is considered difficult to root and is usually propagated by seed or grafting. Cuttings of four cultivars, *Juniperus virginiana* 'Burkii', 'Nana Compacta', 'Silver Spreader', and 'Skyrocket' were taken in early winter and treated with a rooting compound containing 8 mg IBA per gram of talc. All rooted well but did so slowly. 'Burkii' rooted in eight months; 'Skyrocket' in six months. Another *Juniperus virginiana* cultivar, 'Kosteri', rooted well when treated with IBA and NAA at 2.5 mg per gram, or with IBA at 8 mg per gram of talc.

Grafting

Many cultivars of *Juniperus chinensis, J. scopulorum, J. squamata* and *J. virginiana* are difficult to root in practical percentages and usually are grafted. *Juniperus rigida* and *J. turkestanica* do not root and are always grafted. *Juniperus virginiana* and *J. chinensis* 'Hetzii' are compatible with all junipers and are commonly used as understocks. Some *Juniperus virginiana* varieties have been grafted on *J. horizontalis* 'Plumosa' and *J. sabina* understock as well.

Scions taken in December, January and February can be side-grafted on established understock.

Cuttings to be used as understocks will be ready by January if inserted in September or October.

The following cultivars of *Juniperus* are commonly grafted: *Juniperus chinensis* 'Ames', 'Blaauw', 'Iowa'; *J. scopulorum* 'Blue Heaven', 'Moffetii', 'Pathfinder', 'Sutherland', 'Tabletop', 'Welchii'; *J. virginiana* 'Burkii', 'Canaertii', 'Cupressifolia', 'Glauca', 'Hillii', 'Manhattan Blue'.

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LARIX: **Larch**

Larches are found in the cold regions of the Northern Hemisphere. There are about ten species in the genus.

Propagation of the larches is by seed, except for their cultivars which are grafted. Male and female cones are borne separately on the same tree. The female cone is erect, round-to-oblong, maturing during autumn of its first year. Seeds are dispersed in autumn or spring following cone-ripening, but the empty cones remain on the tree following dispersal for an indefinite period of time. After collection, seed can be separated from cones by screening and then stored dry in sealed containers at 40° F. Larch seed germinates fairly well without pretreatment, but benefits from stratification for one or two months prior to sowing in March or April.

Cuttings of *Larix* are considered difficult to root, though softwood cuttings of *L. sibirica*, *L. laricina*, and *L. griffithii* have rooted in small percentages when treated with a rooting compound containing IBA at 8 mg per gram of talc. Cultivars can be grafted on established understocks of *L. decidua* in winter. A whip-and-tongue graft can be used.

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METASEQUOIA: **Dawn Redwood**

Metasequoia is a monotypic genus, introduced to the West from Mainland China in 1947 when an expedition sponsored by the Arnold Arboretum procured seed from a stand of trees in the Shuisapa Valley. Shortly after, diplomatic relations between the United States and China were severed and dawn redwood (*Metasequoia glyptostroboides*) seed could no longer be obtained. It is not known whether the trees in the Shuisapa Valley have survived. Until recently, when trees raised from the original 1947 seed lots began bearing fertile seed, *Metasequoia* was propagated exclusively by asexual techniques.

Sexual Propagation

Male and female cones of *Metasequoia* are borne on the same tree. The female cones are small, pendulous and egg-shaped, with numerous thick scales which, upon ripening in autumn of their first year, release seed for wind dispersal. The empty cones persist on the trees for at least part of the first winter. Closed cones are ready for collection by late October, about the time the leaves fall. The seeds of *Metasequoia* are small and flattened, entirely surrounded by two, broad convergent wings. They are easily extracted from the cones by screening.

Little information is available on the storage and germination of *Metasequoia* seeds. Seed from the original 1947 shipment was sown immediately upon receipt at the Arnold Arboretum with no pretreatment. It germinated, but there are no records of germination percentages or times. A small number of the original seeds were saved and attempts were made to germinate them in 1950; this effort failed.

Asexual Propagation

Excellent rooting can be expected from both hard- and softwood cuttings of *Metasequoia.* Hardwood cuttings have been successfully rooted in November or December; softwood cuttings in late June or early July. All can be treated with a root-inducing material containing 3 mg IBA per gram of talc. An open greenhouse bench with bottom heat is suitable for rooting hardwood cuttings. Softwood cuttings should be placed under mist or in polyethylene structures. The approximate rooting time for both is seven to eight weeks.

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MICROBIOTA: **Microbiota**

Microbiota decussata, the only species in its genus, is a small evergreen shrub, related to *Juniperus* and native to southeastern Siberia.

"Cuttings of ripened wood (brown at base) with a heel, inserted in 75% peat/ 25% sand, under mist, with the medium at 65°–75° F rooted 50% when taken in mid-June." D.M.H.

MICROCACHRYS: **Microcachrys**

This monotypic genus of evergreen shrubs is related to *Podocarpus* and native to Tasmania.

Cuttings may be taken from the tips of vigorously growing twigs and rooted under mist or polyethylene. Rooting without hormone treatment takes six to nine months.

"Cuttings of ripened (and frosted) wood (brown at base) with a heel inserted in 75% peat/ 25% sand, under mist, with the medium at 65°–75° F, rooted 60% in 3 months, when taken in February." D.M.H.

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MICROSTROBUS: **Microstrobus**

This genus contains two species of evergreen shrubs and is related to *Dacrydium*, *Diselma*, and *Microcachrys*. One species is native to Tasmania; the other, to New South Wales.

These plants may be propagated from cuttings. However, while callus forms freely, root production often is not good. Cuttings may be taken from the tips of vigorously growing twigs. Mist is recommended, or the bench may be covered with plastic. Without hormone treatment, rooting takes six to nine months.

M. fitzgeraldii

"Ripe cuttings taken in September rooted 50%. It is easy to establish." D.M.H.

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PAPUACEDRUS: **Papuacedrus**

Papuacedrus is a genus of three species endemic to New Guinea; all have been transferred from *Libocedrus* by H. L. Li. Plants are monoecious with ovoid female cones of four scales; the outer two sterile, and the inner two each with two seeds.

Seeds of *Papuacedrus papuana* sown one month after collection germinated in five weeks without pretreatment. Seedlings were established without difficulty.

Subsequent propagation of the seedling plants was by cuttings treated with 8 mg of IBA and 150 mg of Thiram per gram of talc. High rooting percentages were obtained in four months under mist or in a polyethylene propagating structure.

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PHYLLOCLADUS: **Phyllocladus**

Six species of evergreen trees or shrubs native from the Philippines to Tasmania and New Zealand comprise this genus.

Cuttings may be taken from the tips of vigorously growing twigs. Mist is recommended, or a polyethylene propagating structure may be used. Rooting, without hormone treatment, takes six to nine months.

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PICEA: **Spruce**

About forty species, native to the cold and temperate regions of the Northern Hemisphere, make up this evergreen genus. Except for its cultivars, *Picea* is usually propagated by seed.

Sexual Propagation

Male and female cones are borne on the same trees. The female cone is egg-shaped and hangs from twigs of the previous year's growth. Its scales are thin and sometimes pointed, each supporting two, oblong winged seeds which are released by most species for dispersal by the wind during autumn of their first year. (The cones of *Picea abies* open over a long period of time, releasing their seeds from autumn to early spring. *Picea mariana* cones release their seeds over a period of two to three years.) Cones should be collected in the fall, after they turn brown but before they open. Once the cones have opened, seeds may be separated from them by screening. When held under ordinary storage conditions at room temperature, *Picea* seeds retain their viability for several years. In sealed containers held at 40° F, they may retain viability for up to ten years.

Dormancy of spruce seed varies with the species and seed lot. Most lots show embryo dormancy and benefit from a three-month period of cold stratification at 40° F. *Picea mariana* and *P. sitchensis* germinate in fair percentages without any pretreatment, but a period of cold unifies and shortens the time required for germination.

Asexual Propagation

Cutting

Cuttings of numerous spruce cultivars showing dwarf characteristics can be rooted in worthwhile percentages. Dwarf and abnormal forms of *Picea abies, P. glauca, P. mariana, P. omorika, P. orientalis* and *P. pungens* have been rooted from cuttings consisting of two or three growth flushes taken in October, November and December.

They were treated with a rooting compound containing 8 mg IBA per gram of talc, plus a fungicide, and rooted in about three months.

In one test involving *Picea pungens*, softwood cuttings were taken when new growth was 2 to 4 inches long and terminal buds were starting to appear. The leading shoots proved more difficult to root than comparable wood on the six or so lateral growths immediately behind. All these cuttings were treated with a rooting compound containing 3 mg IBA per gram of talc and placed outdoors under mist. They rooted in high percentages and were ready to be potted by the end of September.

Grafting

There appears to be wide latitude in the selection of understock for clones of *Picea*, though many nurserymen consider *P. abies* to be the most satisfactory understock for all taxa. Scions can be taken in December, January or February and side-grafted on established understock potted one growing season in advance of use.

These graft combinations have survived for many years at the Arnold Arboretum.

Rootstock	Compatible Scion
Picea abies	*Picea abies*
	P. glauca
	P. jezoensis
	P. mariana
	P. orientalis
	P. pungens
	P. purpurea
	P. rubens
P. glauca	*P. abies*
	P. aurantiaca
	P. mariana
P. omorika	*P. obovata*
P. pungens	*P. abies*
	P. aurantiaca
	P. pungens

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PILGERODENDRON: Pilgerodendron

A monotypic genus of evergreen tree, *Pilgerodendron* is related to *Libocedrus* and *Calocedrus*, and is native to Chile.

Pilgerodendron uviferum

"Semi-ripe cuttings taken in mid-November rooted 65%, but were not easy to establish." D.M.H.

PINUS: **Pine**

The genus *Pinus*, with about ninety species, is one of the most widely distributed genera of trees native to the Northern Hemisphere. It ranges from the Arctic Circle to below the Equator at one point in Sumatra.

Sexual Propagation

Male and female cones of the pines are borne separately on the same tree. Pollination takes place during late spring and early summer, but fertilization is delayed until the following spring. The resulting cone is quite woody and is composed of thick, closely packed scales. These vary greatly in size and shape, depending on the species. Cones of most pines mature in autumn of their second year, opening to release two seeds per scale for dispersal by the wind. Serotinous cones of the so-called "fire" pines (*Pinus attenuata, P. radiata, P. contorta* var. *latifolia, P. muricata* and *P. pungens*) remain on the tree for many years after they mature, dispersing their seeds only following the intense heat of a forest fire. Cones of other pines, such as *P. banksiana* vary in behavior. Some open immediately upon maturity while others are serotinous.

Pine cones should be collected in late summer or autumn before they open and after they begin to turn brown. Seed can be separated from open cones by screening. Longevity in storage varies enormously with the species. Fire pine seed remains viable in cones on the tree for long periods, while seed of other species is more perishable and may deteriorate within a year of collection if not held under controlled storage conditions. Its viability is extended by storing it dry in sealed containers at 40° F.

The flotation technique for separating viable from non-viable seed must be modified for some pine species. *Pinus bungeana* and *P. aristata* seeds, for example, have an air chamber which makes even sound seed buoyant for about a day after it is placed in a column of water. By the second day, separation has occurred and sound seed has sunk to the bottom while void seed remains afloat.

Seed of many pine species benefits from a period of cold stratification, though some germinates in high percentages when sown directly. Germination behavior varies widely depending on the species and seed lot. *Pinus banksiana, P. bungeana* and *P. pungens* require no cold period, though germination of seed that has been stored for long periods may be unified by stratification. *Pinus aristata, P. cembroides* var. *monophylla* and *P. virginiana* should be stratified at 40° F for an eight-month period. *Pinus strobus* and *P. taeda* require two months of stratification, and *P. armandii, P. balfouriana, P. flexilis* and *P. peuce* three months. Four months should be allowed for *P. albicaulis* and *P. monticola; P. cembra* may require up to nine months. In the event that the cold requirement of seeds is not known, a three-month cold treatment is recommended; it will do no harm to those seeds not requiring it. Some pine seed (*Pinus cembra, P. albicaulis, P. flexilis, P. cembroides* var. *monophylla* and *P. monticola*) benefits from acid scarification.

Asexual Propagation

Grafting

Rooting of pine cuttings is difficult, and asexual propagation is usually accomplished by grafting.

As a simple rule, the number of needles per fascicle can be used to gauge grafting compatibility. Two-needled pines are generally compatible with other two-needled pines; the same is true for three-needled species. Five-needled pines are *always* compatible with other five-needled pines. There are, however, exceptions to this general rule. For example, *Pinus bungeana* and *P. rigida*, both three-needled pines, are not compatible. *Pinus bungeana* has proven compatible with a five-needled pine, *P. strobus*. *Pinus rigida* cultivars should be grafted on their parent species. A more useful rule may be that pines in the same subgenus are apt to be compatible. Classification of pines may be determined by checking a standard reference.

These graft combinations have survived a significant number of years at the Arnold Arboretum.

Rootstocks	Compatible Scions
Pinus nigra	*Pinus densiflora*
	P. heldreichii
	P. nigra varieties and cultivars
Pinus resinosa	*Pinus densiflora*
	P. heldreichii
	P. heldreichii leucodermis
	P. nigra caramanica
	P. ponderosa 'Pendula'
	P. resinosa cultivars
Pinus strobus	*Pinus aristata*
	P. ayacahuite
	P. bungeana
	P. cembra
	P. cembra 'Stricta'
	P. cembroides
	P. flexilis
	P. holfordiana
	P. hunnewelliana
	P. koraiensis
	P. parviflora varieties and cultivars
	P. peuce

	P. pumila
	P. strobus varieties and cultivars
	P. wallichiana
	P. wallichiana zebrina
Pinus sylvestris	*Pinus densiflora*
	P. densiflora 'Globosa'
	P. mugo
	P. mugo rostrata
	P. sylvestris varieties and cultivars

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PODOCARPUS: Podocarpus

The genus *Podocarpus* consists of about one hundred species of evergreen trees and shrubs widely distributed in warm regions of the Southern Hemisphere and tropical regions of the Northern Hemisphere. These broad-needled plants can be increased by seed or cuttings. The oval nut-like seed is borne at the top of a fleshy, often red-colored, stalk. Seed sown in late winter will germinate in good percentages, but slowly. Cuttings should be taken from terminal shoots of the current season's growth in late summer or early autumn. They should be inserted in a sandy medium in a polyethylene propagating structure or under mist.

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PSEUDOLARIX: **Golden-larch**

This monotypic deciduous genus is native to China and bears male and female cones on separate branches of the same tree. It can be propagated by seed. Cones are yellow-brown and rosette-like in form, composed of numerous woody triangular scales. The winged seeds are released to wind dispersal in late October when the cones shatter, about the same time the tree sheds its leaves. For propagating purposes cones should be collected just prior to this, in early or mid-October. Seeds and scales are somewhat similar in size but differ in weight. They can be separated by fanning techniques.

Golden-larch (*Pseudolarix amabilis*) seed loses viability quickly when kept in dry storage. However, seed stored in sealed containers at 40° F germinates well after one year. Seed sown without pretreatment germinates erratically, but a two-month period of cold stratification produces a uniform stand of seedlings in about ten days.

Asexual Propagation

Rooting of cuttings is not necessary since the plant grows readily from seed. Cultivars may be grafted using seedling understocks of the species.

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PSEUDOTSUGA: **Douglas-fir**

The five or six species of evergreen trees in this genus are native to North America, Japan and China. Douglas-fir can be increased by seeds, cuttings or grafts.

Sexual Propagation

Male and female cones are borne on the same tree, on branches of the previous year's growth. The female cone, brownish in color, bears two seeds per scale. Cones may be collected in August or September and air-dried. Seeds can be separated from cones by screening and fanned to remove chaff. Both *Pseudotsuga menziesii* and *P. macrocarpa* seeds have retained viability for four years when stored in sealed refrigerated containers. Embryo, and quite possibly seedcoat, dormancy inhibit germination of Douglas-fir seed. Germination rate, and in some cases germination percentage, are improved by stratifying the seeds for one to two months at 40° F. Seedlings transplant easily.

Asexual Propagation

Cuttings taken in late winter rooted in high percentages after treatment with IBA. Those taken in fall or early winter were less successful. The best cuttings were made from year-old wood of the past season's growth. In one instance rooted cuttings failed to develop a well-defined leader by their third season. Douglas-fir cultivars can be side-grafted in winter on established understock of the species.

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SAXEGOTHAEA: Prince Albert's Yew

Saxegothaea contains a single species of evergreen tree, distantly related to both *Podocarpus* and *Araucaria*. It is native to Southern Chile.

"Ripe cuttings (after frost) rooted 99% when inserted in mid-January, 3 months to root. Fairly easily established." D.M.H.

SCIADOPITYS: Umbrella Pine

Sciadopitys is a monotypic genus native to Japan. It may be propagated by seed or cuttings but is of extremely slow growth. Many years are required to produce plants of usable size.

Male and female cones are borne on the same tree. The woody female cone with thick scales ripens the second season. When sowing *Sciadopitys* seed, care must be taken to cover it no more than ¼ inch. *Sciadopitys* seed germinates erratically in three to four months. Efforts to shorten and unify germination by stratification have not been effective.

Cuttings taken from terminal growths in June or July root in fair percentages by mid-October. January cuttings, taken from lateral branches of the most recent year's growth on fifty-year-old trees, rooted in five months when treated with a compound containing NAA. April cuttings from the same trees rooted well in six months when treated with IBA at the rate of 8 mg in a gram of talc. Cuttings taken in April from seven-year-old trees and treated with IBA rooted well in eight months.

It has been said that rooted cuttings of *Sciadopitys* lead to trees of poor shape. To investigate this, seedlings and rooted cuttings were grown side by side in the Arnold Arboretum nursery. The seedlings exhibited variable growth rates and plant shapes, while the rooted cuttings duplicated the form of the tree from which they were taken.

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SEQUOIA: Coast Redwood

This evergreen tree is native to the Pacific coast of North America. A single species, *Sequoia sempervirens*, is recognized. Except for its cultivars, *Sequoia* is generally propagated by seed. Male and female cones are borne on the same tree. The small egg-shaped female cones mature at the end of their first season but may persist for many years after the seeds are released. Ripe seed is light brown and flattened.

It may be collected in October, as soon as the cones turn yellowish in color. Drying of cones takes ten to thirty days but may be hastened by heating them in a kiln or oven to about 120° F, after which seeds can be separated from cones by screening. Usually, a high percentage of non-viable seed is present. Sound seed should be stored in sealed containers at 40° F to preserve viability. The seed is ready to germinate soon after release, but germination percentage is often improved by a period of cold stratification. Following germination, young seedlings require more water than do most gymnosperm seedlings.

Both hardwood and softwood cuttings are reported to root well. *Sequoia* cultivars also may be grafted on established understock in winter using a whip-and-tongue graft.

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SEQUOIADENDRON: **Big-tree**

A monotypic evergreen tree, *Sequoiadendron giganteum*, native to California, makes up this genus. Big-tree is generally propagated by seed. Male and female cones are borne on the same tree. The egg-shaped female cones are pendulous and mature in two or more years, remaining attached to the branch following seed dispersal. The stalk that attaches each cone to its branch forms growth rings yearly. These can be used to indicate ripened cones, ready for collection. Cones having three or more rings are mature while those having fewer may not be ripened. Big-tree seeds germinate without pretreatment. The sowing should be determined by the percentage of sound seeds, usually quite low.

Asexual Propagation

Shoots that arise from burls on the trunks of *Sequoiadendron* exhibit juvenility and can be rooted from cuttings. Cultivars can be propagated by grafting, using the species as understock.

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TAIWANIA: **Taiwania**

A large evergreen tree, the monotypic genus *Taiwania* is native to Taiwan and related to *Cunninghamia.*

Cuttings taken in mid-September, with or without treatment with IBA, rooted 24–46% in 150–300 days.

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TAXODIUM: **Bald-cypress**

There are three species of deciduous trees in this genus. They are natives of southeastern North America and Mexico. Bald-cypress is commonly propagated by seed. Male and female cones are borne on the same tree. The female cones are small, round and purplish, ripening from late September to November of their first season. The cones bear large, triangular seeds, too heavy to be dispersed by the wind. Water carries them to wet sites along streams and rivers and plays an important part in germination under natural conditions. Freshly gathered seeds sown in autumn lead to a good germination in spring. In greenhouse situations, untreated seed germinates slowly and poorly without pretreatment. Stratification for ninety days at 40° F speeds and improves germination. However, at best only about one-third of the sound seed germinates.

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TAXUS: Yew

Eight species of evergreen trees and shrubs make up the genus *Taxus*. They are native to the northern hemisphere. Male and female cones of all yews except *Taxus canadensis* are borne on different plants. *Taxus canadensis* is monoecious. A single seed is surrounded by a fleshy cone scale that is open at the apex. It ripens early in autumn of its first year and must be collected immediately, since it otherwise is taken quickly by birds and squirrels. Following collection, seed may be separated from the flesh by maceration and flotation techniques.

Yew seed exhibits double dormancy and natural germination does not take place until the summer of its second year. Satisfactory ways of overcoming dormancy in greenhouse situations have not yet been developed. Seed coat impermeability does not appear to be a problem, since neither hot water nor acid treatments have improved germination. In some instances, small lots of seeds have responded to a five-month warm stratification period followed by three months at 40° F. Should seed fail to germinate within several months after this treatment, it can be given an additional three-month cold period. However, yews tend to hybridize freely and seeds from collections such as are found in arboreta cannot be relied upon to reproduce the plants from which they came.

Asexual Propagation

Cutting

Most *Taxus* cultivars may be rooted with ease, the cuttings being taken from August through March and treated with a root-inducing material which contains 3 mg IBA per gram of talc. Some cultivars root without benefit of any rooting compound, though root initiation may take longer. Rooting time varies with the clone. *Taxus cuspidata*, *T. canadensis* and *T.* × *media* usually root in two and one-half to three months. In general *T. baccata* is more difficult to root and often requires a longer period of time. A root-inducing material containing 8 mg IBA per gram of talc should be used when dealing with this species.

Taxus cuttings of large size, comprised of two or three years' growth, root well and produce plants of usable size quickly.

Grafting

Taxus clones difficult to root may be propagated by grafting on rooted cuttings. Any clone which roots easily and forms a good compact root system may be used as an understock. *Taxus cuspidata* 'Nana' and *T.* × *media* 'Hatfieldii' are both satisfactory. Cuttings inserted in October or November can be side-grafted by January or February. They should then be plunged in a mixture of peat and perlite to a depth which covers the graft union.

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THUJA: **Arborvitae**

There are six species of arbovitae: two natives of North America, the others of East Asia. This common genus is easily propagated both sexually and asexually.

Sexual Propagation

Male and female cones of the arborvitae are borne on the same plant. The small female cones are composed of from six to twenty thin leathery scales, each bearing two to five winged seeds. The cones ripen in early autumn, opening soon after to discharge seeds for wind dispersal. The cones should be collected as soon as they turn from yellow-green to light brown. Seeds can be separated from open cones by screening but should not be dewinged since they are easily damaged. At room temperature, *Thuja* seed loses viability quickly. To preserve it, the seed should be stored in a sealed container at 40° F.

Some lots of *Thuja* seed require pretreatment to remove inhibitors while others germinate as soon as they ripen. Variation within a seed lot is also found. To insure germination, all seed should be stratified at 40° F for a period of two months. Germination then occurs uniformly in approximately three weeks.

Asexual Propagation

Cutting

Thuja cuttings appear to root well when taken any time from September to March. They can be treated with a rooting compound containing 3 mg IBA per gram of talc, and placed on an open greenhouse bench or in polyethylene chambers.

Rooting occurs in two and one-half to three months.

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THUJOPSIS: **Hiba Arborvitae**

Plants raised from seed of this monotypic Japanese genus show considerable variation in habit and grow slowly for a period of years. Cuttings taken from erect shoots are the preferred method of propagating Hiba arborvitae (*Thujopsis dolobrata*).

At the Arnold Arboretum, hardwood cuttings taken in November and January and treated with 4 mg IBA in a gram of talc plus a fungicide rooted at the rate of 100%.

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TORREYA: **Torreya**

The six evergreen species in this genus are native to North America and East Asia. *Torreya* is best propagated by seed. Male and female cones are borne separately on different trees. The mature female cones are drupe-like and oval, each containing a single seed with a woody outer coat. They ripen from August to September of their second season and can be collected from September to November. *Torreya* seeds germinate slowly without pretreatment. It is possible that a period of cold stratification would hasten germination.

Summer cuttings from short side shoots of *Torreya* have been rooted. In two instances, cuttings of *Torreya taxifolia* taken at the Arnold Arboretum in autumn and treated with IBA at the rate of 8 mg in a gram of talc rooted in four months.

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TSUGA: **Hemlock**

There are ten species of hemlock; some native to North America and others to Japan, China and the eastern Himalayas. Hemlock is commonly propagated by seed. There is, however, great genetic variation, particularly in Canadian hemlock (*Tsuga canadensis*), and many dwarf and abnormal cultivars have been selected. These must be propagated asexually.

Sexual Propagation

Male and female cones are borne on the same tree. The female cone is solitary, pendulous, and borne at the end of a lateral shoot from the previous year. The cones release winged seeds for wind dispersal, then persist on the tree until summer or autumn of the second year. They are ready for collection in autumn of their first year, when they turn from green to purplish brown. Two seeds are borne per scale; each brown, slightly flattened and with a paper-thin wing. They are easily separated from open cones by screening.

Most lots of hemlock seed show some embryo dormancy and require a period of cold stratification for satisfactory germination. Three months at 40° F is usually adequate. Germination time is approximately three weeks.

Asexual Propagation

Cutting

Hemlock cuttings consisting of two or more years' growth taken in October and November, wounded and treated to a five-second dip in a liquid formulation of IBA and NAA at 5 mg per gram each have rooted well. Placed either on an open greenhouse bench or under polyethylene chambers, cuttings can be expected to root in high percentages in four to five months. Cuttings may also be taken from December through April.

Grafting

In the past, it was customary to propagate all hemlock cultivars by grafting them on *Tsuga canadensis* understocks. Instances of incompatibility between hemlock cultivars and their species, overgrowth of the scion, and girdling, brought about by circling roots which developed on understocks established in small pots, led to failure of the grafted plants shortly after grafting or in subsequent years. Therefore, we now propagate these plants from cuttings. Were we to graft hemlocks, it would be done in January or February on established understocks. A side or veneer graft would be used.

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Tsuga canadensis *'Pendula' (Sargent weeping hemlock). Photo: H. Howard.*

APPENDIX

The products listed below are root-inducing materials which are commercially available.

Product	Manufacturer	Effective Ingredient
Hormodin #1	Merck Chemical Division	1 mg IBA/gm of talc
Hormodin #2	" " "	3 mg IBA/gm of talc
Hormodin #3	" " "	8 mg IBA/gm of talc
Hormo-Root "A"	Hortus Products Co.	1 mg IBA/gm of talc plus 150 mg Thiram
Hormo-Root "B"	" " "	4 mg IBA/gm of talc plus 150 mg Thiram
Hormo-Root "C"	" " "	8 mg IBA/gm of talc plus 150 mg Thiram
Rootone #10	Amchem Products Inc.	5 mg Naphthalene-acetamide/gm of talc
Rootone with Fungicide	" " "	.57 mg IBA plus .33 mg NAA plus .13 mg Naphthylace-tamide/gm of talc plus 40 mg Thiram

GLOSSARY

After-ripening: Period during which changes take place in seeds to prepare them for germination. In nature, such changes are brought about through seasonal variations.

Asexual propagation: Propagation of plants by means other than fertilization. Cuttings, layers, and grafts all are asexual methods of propagation, involving the increase of plants through ordinary cell division and differentiation.

Auxins: Organic substances that organisms produce in minute amounts. In plants their action regulates plant growth, influences flower and fruit production, root initiation, etc.

Basal: At the base of, on cuttings the basal end is that which was closest to the roots of the stock plant.

Bench: A raised structure used in a greenhouse to hold potted or flatted plants, propagating or soil media in which plants are grown. Usually planned so all parts can be reached from aisles. Benches vary widely in design.

Bloom: A powdery surface coating found on some fruits and leaves.

Bud: An undeveloped shoot or flower, usually enclosed by scales or scale-like leaves.

Budding: A grafting procedure in which the scion consists of one bud.

Budstick: A shoot cut from a plant for the purpose of using its buds for bud-grafting.

Callus: A mass of undifferentiated cells that develop around wounded plant tissues. It arises mostly from cambial tissue and is frequently associated with the rooting of cuttings and the healing of graft unions.

Cambium: A layer of meristematic tissue found between bark and wood of woody plants, the cells of which are capable of dividing to produce new tissue. Responsible for the successful regenerative activity of woody plants (i.e. production of roots on cuttings, formation of graft unions, etc.)

Capillary action: The movement of a liquid into fine tubes or spaces because of its surface tension.

Carpel: The female or ovule-producing organ of a flower, composed of ovary, style, and stigma.

Clone (Clon): Defines a category of genetically uniform plants, all propagated from a single individual by vegetative means.

Cold frame: A shallow unheated structure placed on or in the ground out-of-doors and covered with glass or plastic. Used for carrying small hardy plants over winter, propagating seedlings and cuttings in spring and summer, and holding plants between greenhouse and nursery. Mitigates extreme temperature fluctuations.

Cold stratification: Treatment of seeds with a period of moist cold conditions to break internal dormancies.

Compatibility: The degree of affinity between stock and scion of a graft union, as expressed by subsequent growth, vigor and longevity of the grafted plant. Plant parts which form a strong, healthy union when grafted together are said to be "compatible."

Cone: Reproductive structure (often loosely termed "fruit") of the gymnosperms. There are two types of cones: pollen-bearing (male) and seed-bearing (female).

Conifer: Any of the cone-bearing trees or shrubs among the gymnosperms. Includes those plants such as yew and juniper which bear modified cone-like structures.

Controlled storage: Any of various methods used to maintain high viability in seeds until they are needed.

Cotyledons: The primary leaf or leaves of an embryo. They may function as leaves after germination or may contain food reserves for initial seedling growth.

Cultivar: A term derived from "cultivated variety." A taxon known only in cultivation; named, selected and propagated for its desirable characteristics.

Cutling: A plant of any size or age that has been grown from a cutting.

Cutting: A severed portion of a plant, usually capable of regenerating shoots and/or roots which allow it to grow into an independent individual.

Cutting, hardwood: A stem cutting made from the mature woody shoot of a dormant plant.

Cutting, softwood: A stem cutting made from an actively growing shoot which has not yet become woody.

Dioecious: The condition in which cones of each sex are borne on separate plants.

Dormancy: Period during which plants become inactive so they can survive periods of adversity. Quiescent condition in seeds which remains until specific requirements for germination have been fulfilled.

Double dormancy: Dormancy in a seed having two barriers to germination, usually seed coat impermeability plus internal conditions. Sometimes called "two-year" seeds.

Embryo: The rudimentary plant within a seed.

Embryo dormancy: Dormancy due to conditions of the embryo. The embryo requires some environmental stimulus before it will resume growth.

Established understock: A rootstock which has been potted at least one growing season in advance of its use.

External dormancy: Dormancy caused by seed coats which retard the entry of water or oxygen. Sometimes called seed coat dormancy.

Fanning: The process of removing extraneous matter from seeds by using a current of air. Also called "winnowing."

Fascicle: In conifers, a cluster of needles.

Fertilization: Union of the sperm or male sex cell from the pollen grain with the egg nucleus or female sex cell inside the ovule, resulting in the development of an embryo inside a seed.

"Fire" pines: Species of pine whose seeds are not normally released until the cones have been exposed to the heat of a fire.

Fixed juvenile: A plant which fails to pass from the juvenile stage characteristic of seedlings to the adult stage found in mature plants.

Flat: A shallow wood, plastic, or metal tray supplied with drainage holes and used for germinating seeds, rooting cuttings or raising plants. Flats are available in a wide variety of sizes.

Flotation: A technique based on differences in specific gravity for separating seeds from pulp debris. Seeds usually sink when placed in a column of water, while pulp floats and can be poured or floated away.

Frame: See "Cold frame" and "Hot bed."

Fruit: The developed ovary of a flowering plant, including seeds and accessory structures.

Gene: The basic unit of inheritance which determines the characteristics of a plant.

Gene mutation: A sudden specific change in a gene which causes a concommitant change in the characteristics of the plant, or plant part, growing from the cell in which the mutation occurred.

Genetic variation: Inherited variation in the characteristics of a plant.

Genus: A category of classification lower than a family and higher than a species.

Geographical races: Variations of a taxonomic species, based upon subtle deviations from the typical form. Related to specific peculiarities of a climatic region.

Germination: The resumption of growth by an embryo and its development into a seedling. Prior to germination the conditions for breaking dormancy must have been satisfied and environmental conditions must be favorable.

Germinative capacity: The percentage of seeds in a given lot that are potentially capable of germination.

Girdling roots: Roots which establish a circling pattern during confinement in containers, sometimes leading to "strangulation" and death of the plant.

Grafting: The art of joining parts of plants so that they will unite and grow as single individuals.

Graft union: The point at which stock and scion are joined in a grafted plant.

Hardiness: Ability of a plant to survive the climate of a given geographical location.

Hardening-off: Any of various methods used to condition plants so that they will not suffer when transferred from one environment to another.

Hormone: A substance naturally produced in one part of a plant and transported to another part where, in extremely minute quantities, it is capable of producing marked growth effects.

Hot bed: A structure essentially identical to a cold frame, but supplied with supplemental bottom heat by electrical cables, hot water steam pipes, or decomposing manure.

Hybrid: The offspring of a cross between two taxa.

Incompatibility: When applied to a graft union, a lack of affinity between stock and scion, usually expressed by failure, poor or abnormal growth, lack of vigor, or overgrowth, of the stock or scion. Grafted plants which fail to form a satisfactory graft union are said to be "incompatible."

Indolacetic acid: A chemical compound commonly used as a synthetic auxin. When applied to cuttings, it promotes the production of roots. Frequently abbreviated "IAA."

Indolbutyric acid: A chemical compound commonly used as a synthetic auxin. When applied to cuttings, it promotes the production of roots. Frequently abbreviated "IBA."

Internal dormancy: Dormancy due to conditions within the seed, either in the stored food or the embryo.

Juvenility: Physiological condition usually associated with the seedling stage of plants. It may or may not be visibly apparent, and it persists for varying lengths of time.

Lateral: In referring to buds or shoots, one found on the side, rather than the tip, of the branch.

Layer: A plant part which produces its own roots while still attached to the parent plant.

Layering: The development of roots on a stem while it is still attached to the parent plant. The stem is detached after it has formed enough roots to sustain itself.

Loam: Soil having moderate amounts of clay, sand, and organic matter.

Longevity: Length of life. In seeds, the period of time they remain viable under specified environmental conditions.

Maceration: The process of crushing fleshy fruits or cones so that the pulp and seeds can be readily separated by flotation techniques.

Medium: The substance in which plants are grown, cuttings are rooted, seeds are stratified, etc. Plural is "media."

Microsporophyll: In seed plants, a modified leaf-like organ bearing pollen sacs.

Milled sphagnum: Sphagnum moss ground to a particle size suitable for use in sowing seeds.

Mist system: Device consisting of nozzles and control mechanisms designed to keep cuttings from desiccating as they root by maintaining a film of water on the leaves. An *intermittent mist system* operates at intervals frequent enough for the cuttings to maintain their turgor.

Moisture content: In reference to seeds, the amount of moisture contained, expressed as a percentage. It can be significant in the retention of seed viability during storage.

Monoecious: The condition in which cones of each sex are borne on the same plants.

Monotypic genus: A genus comprised of one species.

Naphthalene-acetic acid: A chemical compound commonly used as a synthetic auxin. When applied to cuttings, it promotes the production of roots. Frequently abbreviated "NAA."

Non-viable seed: Seed which lacks the capacity to germinate.

Ovule: Immature seed borne on the scales of female cones in gymnosperms. The ovule contains the female sex cell before fertilization. At maturity, it becomes the seed.

Pathogenic organisms: Organisms capable of producing disease.

Peatmoss: An organic substance formed by partial decomposition of sphagnum moss in water and used by horticulturists to modify soil mixtures and aerate media.

Photoperiod: The relative length of light and darkness in a day. It has marked influence on the behavior of plants.

Pollen: Bodies containing the male cells which fertilize the egg's nucleus to produce an embryo. Borne in sacs on the scales of male cones in gymnosperms.

Polyethylene plastic structure: A structure designed to prevent plant cuttings from desiccating while they are developing roots. It consists of polyethylene plastic film supported by some sort of framework.

Pretreatment: As applied to seeds, any measure used to overcome dormancy in seed before it is sown. Seed coat modification and stratification are methods of pretreating seeds.

Propagant: The plant resulting from any propagating technique.

Propagation: The multiplication of plants by seeds, cuttings, layers, grafts, etc. (See "Asexual Propagation" and "Sexual Propagation".)

Propagule: A plant part capable of growing into a new individual.

Relative humidity: The amount of water vapor in the atmosphere expressed as a percentage of the total amount which the air is capable of holding at a given temperature.

Respiration: The metabolic processes by which a plant oxidizes its food material. Oxygen and carbohydrates are assimilated into the system and oxidation products are given off.

Root-inducing substances: Materials used to stimulate root initiation on cuttings of plants. Those most commonly used are IBA (indolbutyric acid) and NAA (Naphthaleneacetic acid), both artificial compounds which act like natural plant auxins.

Root initials: Groups of cells which arise in cuttings and are the first step in the development of roots. Those already present in shoots before they are removed from the parent plant as cuttings are called "preformed root initials."

Rootstock: The portion of a graft combination which becomes the root system of the grafted individual. Sometimes called "understock."

Rubber budding strips: Rubber strips specifically designed for tying bud grafts and for binding newly made graft unions. They are manufactured in a variety of sizes.

Secondary dormancy: Return to the dormant condition after the initial dormancy has been overcome. Usually caused by unfavorable environmental conditions.

Scale: In female conifer cones, the bract-like appendages which are attached to the central woody axis and which bear seeds on their upper surfaces.

Scarification: Alteration of a seed coat through the use of an abrasive technique so that it becomes permeable to water or air. *Mechanical scarification* involves breaking, scratching, or otherwise mechanically altering the seed coat. *Acid scarification* involves eroding it with acid.

Scion (Cion): The portion of a graft combination which develops into the stem and leaves of the new individual.

Scorching: Parching or shriveling of leaves. Occurs when plants are not properly hardened-off before being moved from one environment to another.

Screening: A process for separating extraneous matter from seeds. The mixed material is passed through a screen with mesh coarse enough to retain either chaff or seeds, but not both.

Seed: A ripened ovule consisting of an embryo and stored food enclosed by a seed coat.

Seed dormancy: Inhibition of seed germination due to restrictive internal, external, or environmental conditions such as those related to temperature and moisture.

Seed coat dormancy: Dormancy due to a seed coat which retards the entry of water or oxygen. Sometimes called external dormancy.

Seedling: Any plant raised from a seed; often used to indicate such a plant while it is young in age.

Seed lot: A batch of seeds, usually from a single, specific source, which may be of any quantity.

Seed pan: A shallow pot of clay or plastic, available in a wide range of sizes. About two-thirds the depth of a standard pot.

Serotinous: Flowering or fruiting late in the season. Applied to cones of gymnosperms that remain closed on a tree for prolonged periods after they have matured.

Sexual propagation: Propagation of plants by seeds, formed upon the union of sperm and egg cells.

Shield budding: A grafting procedure in which the detached scion bud and wood resembles a shield. It is inserted into a "T"-shaped incision in an understock.

Shoot: A flush of growth arising from a single bud.

Side graft: A grafting technique in which the scion is inserted in the side of the understock. The topgrowth remains, sustaining the plant until the scion has made growth.

Simple layer: A layering technique in which a plant is propagated by bending a girdled branch into a trench, fastening it down, and covering it with soil to induce it to produce its own roots.

Species: A category of classification lower than a genus or subgenus and above a subspecies or variety. The basic category of classification. In nature, individuals of one species normally interbreed.

Sphagnum moss: Any mosses of the genus *Sphagnum*, found in wet, boggy areas and valued for their water-retaining and antibiotic qualities.

Standard: A plant grown with a single, erect, tree like stem. Often achieved by budding or grafting on a tall stem.

Stratification: Any process used to encourage germination of dormant seeds which require pretreatment by time, temperature, and moisture.

Stratification medium: Any material used to keep seeds moist during stratification; often organic peat, sand, or sawdust.

Synergy: The effect of two or more substances which together have a greater effect than the sum of their individual effects.

Taxon: A term referring to any taxonomic unit, such as species, variety, or cultivar. Plural is "taxa."

Terminal: In the propagation of plants by cuttings, the terminal end is the distal part of a branch.

Transpiration: The evaporative loss of water vapor from leaves.

Turgor: The firmness of plant tissues as influenced by the fluid content of cells.

Understock: See "rootstock."

Variety: A category of classification within a species based on hereditary differences from the species. A wild population of plants differing from other varieties in one or more characteristics, but not sufficiently different to be a species.

Vector: An organism which acts as a carrier, i.e. of seeds, diseases, etc.

Vegetative dormancy: Resting condition of plants or vegetative parts of plants, such as buds or roots, due to low temperatures, drought, or the presence of inhibiting hormones.

Vegetative propagation: See "Asexual propagation."

Veneer graft: A type of side graft.

Vermiculite: A product manufactured by expanding mica under high temperatures. It is light in weight and retains water and nutrients but does not hold its structure well.

Viability: Capacity to renew growth; in seeds, the ability of a certain seed lot to germinate and grow under favorable circumstances, expressed as a percentage.

Warm stratification: Warm pretreatment of seeds under moist conditions at about room temperature to bring about external or internal change. Such treatment precedes cold stratification.

Whip-and-tongue graft: A grafting technique in which the topgrowth of the understock is removed prior to grafting. Tongues are cut into the sides of rootstock and scion and the two are fitted together to form the graft union.

Wing: A membranous appendage to a seed which facilitates wind dispersal.

Winnowing: See "Fanning."

Woody: The parts of trees and shrubs which persist for more than one year. Often qualified as to degree of maturity, i.e. softwood and hardwood cuttings, etc.

Wounding: A term used to define the slitting, cutting, or otherwise damaging of the basal ends of stem cuttings. It can remove a physical barrier to root emergence, expose more surface to the action of root-inducing materials, and lead to more extensive root systems.