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# SEED PROPAGATION

## Of Native California Plants

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Published by
**Santa Barbara Botanical Garden**

This easy-to-use reference is designed for the increasing numbers of serious home gardeners, commercial nursery professionals, and members of the professional horticultural and botanical communities who want to propagate the native flora of California. Such information is vital if we are to meet the challenges of limited water for our landscapes, revegetation of our open space, and the preservation of endangered species. We hope that you will find this book a useful addition to your gardening library.

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# 1. Preface

Seed Propagation of Native California Plants was originally published as one of a series of leaflets by Santa Barbara Botanic Garden over (50) years ago (Leaflet #10, February 1964). Although long out of print, the leaflet is still in demand. Over the last twenty years the interest in and use of native California plants has increased, as has the knowledge of their seed morphology and physiology. This revised and greatly expanded edition of Seed Propagation of Native California Plants incorporates the additional knowledge and experience gained by this author and other re searchers in propagating native California plants from seed.
The greatest advances in seed germination research have been made in the use of chemical treatments to break seed dormancy. Sulphuric acid is still the only chemical treatment used at the Santa Barbara Botanic Garden. However, a number of chemical treatments are included in this publication, mainly to indicate direction and potential.

Dara E. Emery (1922-1992) is recognized as one of the foremost experts on the propagation of California's native plants. Mr. Emery joined the Santa Barbara Botanic Garden in 1950 as its first horticulturist and in that capacity he was responsible for growing the thousands of plants propagated annually for the Garden. Mr. Emery learned to successfully grow all types of California natives and this book is based on the results of over 20 years of his experimentations with these plants. In addition to his propagation studies, Mr. Emery initiated a native plant selection and breeding program at the Garden and more than a dozen new cultivars have been introduced into the nursery trade as a result of his work. Mr. Emery is widely acknowledged for his contribution to the advancement of native plant horticulture throughout California.

# 2. Introduction

California has a diverse flora that is widely used in cultivation. California native plants were successfully introduced into European gardens over 100 years ago from collections of botanical explorers visiting the west coast of North America. In recent years there has been a steadily increasing interest in the use of native plants in California gardens. They offer great landscaping possibilities, are relatively disease and pest free, and often have low maintenance requirements.

Currently, a diverse array of native species is available from at least some wholesale growers, but any one retailer is apt to stock only a few. Many species that are desirable for cultivation are best grown from seeds and often these require special germination procedures. This book is, therefore, designed as a guide to the seed propagation of California native plants. The first part consists of comments on methods used in collecting and propagating such plants from seeds. It includes descriptive information on different pre-sowing treatments and seed germination temperatures; some seeds have very narrow limits of tolerance. There is also a section on general methods for propagating annual wildflowers from seeds. The major part of this publication is a list of suggested pre-sowing treatments for seeds of over 900 species and varieties of California native plants.

I am taking this opportunity to acknowledge and to thank our recent director, Ralph Philbrick, for his help and suggestions; our editor, Mary Carroll, for her help and patience in the preparation of this manuscript; Carol Bornstein and Dennis Odion for reading the manuscript; our librarian, Nancy Hawver, who obtained most of the references used; our taxonomist, Steve Junak, for checking the nomenclature; our computer operator, Lilla Burgess, for her typing and patience with the many changes necessary; our production editor, Laura Baldwin, for designing and producing the final book; and others who made suggestions.

The Santa Barbara Botanic Garden is a private, non-profit educational and scientific institution dedicated to the study, display and conservation of the native flora of California and the California Floristic Province. Located on 65 acres in the foothills above Santa Barbara, the Garden is a living museum that offers visitors a glimpse of plant communities through out the state. In addition to serving the community as a distinctive educational, botanical, and horticultural resource, the Botanic Garden is a delightful place to experience nature firsthand. For information on programs, membership, general information or orders of this publication write to Santa Barbara Botanic Garden, 1212 Mission Canyon Road, Santa Barbara, California 93105, or call (805) 682-4726.

## 3. Seed Collection and Storage

Seeds of native California species are not always easy to obtain; but seeds of a number of species, particularly annuals, can be purchased from seed companies and seed collectors. Still others are occasionally available from botanic gardens throughout the state. Often, however, it is necessary for the propagator to collect them himself. Seeds should be harvested only from healthy plants showing no sign or the least sign of disease or insect damage. All drying seeds must be protected from birds and rodents.

Seeds that are wind dispersed or borne in fruits that, upon drying, dehisce (or discharge) must be harvested when slightly green or immature; they can then be dried in loosely covered containers. Lupine (Lupinus) and poppy (Eschscholzia) are examples of plants that discharge their seeds at maturity and therefore must be harvested just before fully ripe. California lilac (Ceanothus) capsules must also be picked when slightly green and dried in a screen-covered container at day temperatures of 85° to 100°F. If dried at much lower temperatures, the capsules may not open, and then they must be thrashed by pounding with a heavy object in order to separate the seeds and chaff. It is important to note that seeds found to contain milky or gelatinous substances are too immature to harvest.

Fleshy fruits such as those from nightshade (Solanum), barberry (Mahonia), and gooseberry (Ribes) should be crushed, and the mashed pulp containing the seeds should be spread in a thin layer on paper to dry. The seeds and pulp can then be readily separated. Another method is to add water to the mashed pulp and seeds, preferably in a tall container. After standing for a day or two, the seeds and pulp will separate.

If seeds are to be stored for future use, thorough drying is necessary to prevent mold and to insure reasonable longevity. With a few exceptions, noted below, the harvested seeds or fruits should be placed in a warm ( 85°-100°F day temperature), dry place for several weeks. They should be protected from dew during this period. After being cleaned, the seeds should be placed in appropriately sized envelopes or bags (labeled with name and date) and placed in a sealed container with several crystals of a moth larvicide for a day or two to kill any seed-eating insects or their eggs.

The longevity of seeds of California native plants is highly variable and depends upon the species. Willow (Salix) and poplar (Populus) seeds are extremely short-lived. They remain viable for only a few hours. They die in the wild, unless they are dispersed promptly to a moist substrate like a stream bank. Species of oak (Quercus), buckeye (Aesculus), chinquapin (Chrysolepis), hazelnut (Corylus), maple (Acer), and snowdrop bush (Styrax) also have short-lived seeds that must be sown before they dry out, usually a month or so after harvesting . Conversely, some lupine (Lupinus) seeds have given fair germination after 30 years of storage at room conditions. Short-lived seeds should be sown as soon as they have been harvested and cleaned. If they must be held over from fall harvest for spring sowing, they should be stored under cold, moist conditions (see cold stratification).

Moderate to long-lived seeds are best stored in cold, dry conditions such as in the refrigerator in a closed container to which a packet of desiccant s been added. Packets of desiccant are obtainable at a pharmacy. Seeds of most species, unless known to be long-lived (those with impermeable seed coats), can be stored two or three years in a cool, dry room; however, if stored as suggested in a refrigerator, they will remain viable for several additional years.

## 4. Seed Dormancy and Treatments

Germination is the resumption of active growth of the seed's embryo. It requires moisture, proper temperature, and oxygen. The time necessary for complete germination varies with the species. Seeds of most annual wildflowers germinate with no difficulty in one to two weeks. Seeds of many longer-lived plants take three to six weeks; however, some take up to several years to germinate under natural conditions. Since slow and sporadic germination is usually the result of some form of seed dormancy, treatment to break the dormancy just prior to sowing are often used.

In general, there are two types of seed dormancy: seed coat dormancy and internal dormancy. Seeds with seed coat dormancy usually have a seed coat that is impermeable to oxygen and /or water. Occasionally the dormancy is caused by an inhibiting chemical in the epidermis or adjacent interior membranes. Under natural conditions these seeds remain on or in the ground without germinating until they have weathered sufficiently to allow penetration of water, exchange of gases, or neutralization of inhibiting chemicals. Seeds of some species germinate only after being subjected to fire. The length of time involved - it can be several years or more depends upon the species and the environmental conditions. Seed coat dormancy is common in California lilac (Ceanothus), manzanita (Arctostaphylos), sumac (Rhys), and many members of the legume family. If seeds of such plants are harvested when slightly green or immature and sown immediately before they dry out, germination problems may be reduced; however, once the seeds have dried out, the dormancy factor is present and must be counteracted to obtain prompt germination. Methods of breaking seed coat dormancy include scarification, hot water, dry heat, fire, charate, acid and other chemicals, mulch, water, cold and warm stratification, and light. For a detailed article on water-impermeable seeds (seed coat dormancy), see Rolston (1978).

Internal dormancy is a general term encompassing a number of physiological conditions that delay germination. Not all of these conditions are fully understood or easy to counteract. The most common one is called after-ripening. Seeds that require an after-ripening period, even though harvested when mature, germinate poorly or not at all until they have been subjected to moisture and either high or low temperatures or both in sequence; sometimes, however, a period of dry storage is sufficient to break dormancy. As might be expected, internal dormancy is most often found among species that grow in the high mountains or deserts. For the montane species, a moist cold period is required, simulating a cold winter.

For some desert seeds a few weeks of dry storage at over 100°F, simulating summer desert heat, is necessary; then the seeds will germinate at lower temperatures. The more common method for breaking internal dormancy is cold stratification. In some cases, the use of chemicals can be substituted for part or all of the stratification requirement.

Multiple dormancy factors also occur. In one general type there is seed coat dormancy plus internal dormancy. Seeds with this dormancy combination must be treated for the impermeable seed coat first, then for internal dormancy. In another type there are two or more distinct internal dormancy factors, which unlock sequentially at different temperatures. One group requires warm temperatures first for a small amount of primary root growth, then cold to break shoot bud dormancy, then warm again to initiate shoot growth and complete germination. Another group needs cold temperatures first to break primary root dormancy, then warm to initiate a small amount of root growth, then cold again to break shoot bud dormancy, then warm again to initiate shoot growth and complete germination. In the wild, seedlings of plants with these dormancy types would not appear until the first or second spring after the seeds had matured and dropped from the parent plant. For a detailed discussion of dormancy and germination in nature, see Gutterman (1980-1981). A general summary of practical methods for breaking seed dormancy is outlined in the next few pages. Recommendations for appropriate seed treatments of specific plant species are included in the (CNPS Calscape plant pages).

**Scarification**

Mechanical scarification can be accomplished by rupturing the seed coats with sandpaper, a file, a pin, or a knife. Even a vise can be used to squeeze seeds along the suture until they crack open. Care must be taken not to injure the embryo. It may be necessary to open a couple of seeds to see where the embryo is located in relation to the micropyle, the former point of attachment to the fruit. Large seeds like those of the bush lupine (Lupinus) are easily scarified with a knife; the hot water treatment is easier for small seeds.

**Hot Water**

For small to medium-sized seeds or large quantities of seeds, the hot water treatment is more practical than scarification. For this treatment seeds should be dropped into about six times their volume of 180°-

200°F water (rain water is desirable if it is near neutral in pH) . They should be left to cool and soak in the water for 12 to 24 hours, after which they are ready for sowing. The container used for this treatment should not be made of aluminum as it may be toxic to the seeds. Also softened water should not be used since the amount and ratio of salts may be toxic to the seeds. Another and more drastic hot water treatment is sometimes used for especially thick or hard-coated seeds. For this treatment, the seeds should be placed in vigorously boiling water for a specific length of time depending on the species, then immediately removed from the boiling water and cooled in cold water. With both hot water treatments, the seeds should be sown promptly and not stored again.

**Dry Heat**

Oven or dry heat is not often recommended, and the temperatures required are more suitable to an incubator than a kitchen oven. For this seed coat treatment the seeds should be placed in shallow containers in a preheated incubator or oven. The specific temperature and duration depend on the species. After the treatment, the seeds should be cooled immediately and sown.

Where the temperature suggested is between 180°- 212°F, it is possible that the hot water treatment of the same temperature and for the same length of time would give comparable results.

**Charate**

The char from burned plant stems has been shown to be a good neutralizer of germination inhibitors in the seeds of several herbaceous species associated with chaparral fires (Keeley & Keeley 1982). These authors report that of the fire-followers tested [snapdragon (Antirrhinum), pincushion flower (Chaenacti), whispering bells (Emmenanthe), golden yarrow (Eriophyllum), and Phacelia species], all had greatly enhanced germination with the addition of a small amount of chamise (Adenostoma fasciculatum) charate to the sown seeds.

Charate can be prepared by burning chamise stems of 3/8th inch or less in diameter with a propane torch until they are blackened through and then grinding the charred stems in a Wiley mill to produce a uniform powder.

The Keeley's applied 0.154 ounces of charate to each petri dish of 20 to 50 seeds. Charate made from woody species other than chamise gave different degrees of germination enhancement for different species (Keeley & Keeley 1982). Baking the stems (500°F for 10 minutes or 347°F for 30 minutes) instead of treating with a blowtorch may give comparable results. In some cases, seeds heated in an oven for short periods and then treated with charate showed further enhanced germination, sometimes synergistically.

In the family Hydrophyllaceae there are many fire-following species with seeds that are difficult to germinate. These include whispering bells (Emmenanthe), yerba santa (Eriodictyon), Eucrypta, Phacelia, and poodle dog bush (Turricula). Whispering bells and species of Phacelia have been tested with charate, and in each case, germination has been enhanced.

**Fire**

Seeds of some genera have tough, thick seed coats and germinate most satisfactorily when subjected to the heat of fire. For this treatment the seeds should be sown in the fall in a slightly moist medium but not watered. A layer of dry pine needles or excelsior, four to six inches deep, should be placed over the top of the seedbed. A few small pieces of wadded paper will help to ignite the material. One or two strips of aluminum foil placed over the exposed edges of the wood container will prevent it from burning; plastic containers should not be used. After the seedbed has cooled following burning, it should be thoroughly watered and then treated as any other batch of sown seeds. Since the small flash fire produced by this treatment is quite hot, this method should be used outdoors in the open, away from combustible material, and on a calm day.

The seeded container should be left outdoors for germination, since seeds of many plants also have internal dormancy factors and therefore need a cold, moist period for germination. Even using this treatment, manzanita (Arctostaphylos) seeds require a minimum of two months to germinate. If the seeds are sown and treated in mid-October and no germination has occurred by June, the seedbed can be dried out for the remainder of the summer. Watering should be resumed in the fall when the weather begins to cool. Some germination may occur as late as the following spring.

This fire treatment is not exact, and the results obtained may not be consistent because the amount and duration of heat actually reaching the seeds is governed by several variable factors.

**Acid**

Acid treatments are often used to break down especially thick impermeable seed coats. Since seeds placed in concentrated sulfuric acid (H2 S04) will become charcoal in time, the temperature of the acid and the length of time the seeds are soaked are very important. The acid should be used at room temperature for a period of a few minutes to several hours depending on the species. The seeds should be immersed in acid in a glass, china, or earthenware container, and should be stirred occasionally with a glass rod; however, too much stirring will cause the acid to heat undesirably. The seeds must be removed from the acid just before any acid penetrates the seed coats. When the allotted time is finished, the seeds should be removed promptly and washed thoroughly in several changes of water to neutralize completely all remaining acid. For some species the duration of the acid bath depends on the specific batch of seeds and can only be determined empirically. After treatment and a thorough washing, the seeds may be sown or dried and stored for several months.

Since sulfuric acid is caustic and dangerous to handle, its use is recommended only for those familiar with the use of caustic chemicals. In lieu of the acid treatment for seeds with thick coats, such as manzanita (Arctostaphylos), the fire or mulch treatments can be used. With thinner-coated seeds, hot water or scarification is satisfactory.

**Other Chemicals**

About (70) years ago researchers in various agencies and private industry began experimenting with chemicals to neutralize dormancy conditions present in seeds. Results have shown that inhibiting chemicals can be pre sent in one or more parts of the seed; other dormancy-causing factors (i.e., immature embryos or impermeable seed coats) may also be present in a given seed.

Three chemicals that have proven very helpful in breaking certain types of dormancy are gibberellic acid (GA3), potassium nitrate, and thiourea. The aqueous solutions of these chemicals should be used at room temperature. The concentration and length of treatment depends on the species to be treated. Seeds soaked in GA3 or thiourea should be stirred occasionally and not rinsed afterwards, unless specified, but sown immediately. After this soaking they can also be air-dried and stored for short periods and then sown or given a subsequent treatment. The no-rinse afterwards also applies to the use of potassium nitrate and hydrogen peroxide, other chemicals occasionally recommended as aids to germination. Great care should be taken in working with these chemicals as some are poisonous. Due to their toxic or poisonous nature, some are difficult to obtain; however, in nearly all cases there is an alternate method of seed treatment noted. The main advantages of these chemicals are speed, ease of use, and unaltered physical condition of the seeds following treatment.

**Mulch**

The mulch treatment hastens the microbial breakdown or softening of the seed coats. It is a slow method but is what often occurs in the wild. For this treatment, f ill a six- to eight-inch deep container half full with seedbed medium. Then the sown seeds should be covered with a mulch of wood shavings (not redwood or cedar). A one-inch thick layer of old composted shavings is best; but if not available, a three-inch layer of fresh shavings is satisfactory. If fresh shavings are to be used, they should be soaked a few hours in a bucket of water first and mixed with a compost starter of microbial inoculant (see Germination Media section). Neither the seeds nor the medium should be treated with a fungicide. If this treatment is initiated in early spring or early summer and if the shavings are kept moist all summer, germination will require three to four months or longer, depending on the species. This mulching technique also works well in a ground bed; however, transplanting may be a bit more difficult.

**Water**

For the occasional species whose seed coats contain a readily water soluble, germination-inhibiting chemical, this substance can be removed by soaking the seeds in tap water or by leaching the seeds in slowly running tap water for various lengths of time just prior to sowing. The length of time depends on the species. With the water bath, changing the water every 12 to 24 hours will hasten this leaching process. Softened water should not be used for this treatment.

**Cold Stratification**

Cold stratification for seeds with internal dormancy simulates cold winter conditions. For small quantities of seeds, mix at a ratio of 1:3 or more with moist peat moss or moist vermiculite, place in a tightly sealed polyethylene bag or glass jar, and store in the refrigerator at a temperature of 35°- 41°F. With a few species, freezing the seeds at 28 - 32°F is required.

For bulk seeds, soak in water for a few hours first, then place wet in a sealed container. In either case, the seeds must be kept moist during the entire length of the treatment. This will require periodic checking and the addition of water if necessary. Another reason for periodically checking the stratifying seeds is to see if they have started to germinate. If, for example, a California-lilac (Ceanothus) species has a three-month cold stratification recommendation, it should be visually checked for germination a couple of weeks prior to the end of the third month. If any white root tips are visible, the whole batch should be sown immediately. The longer the radicals are when the seeds are sown, the greater the probability of damage and the greater the mortality rate is apt to be. If the stratification period is inadvertently lengthened, it is usually not detrimental, pro viding the radicals are still very short or not yet showing.

In contrast, to cut the stratification period short by even a few days could be harmful if no radicals are visible. By prematurely discontinuing stratification, primary dormancy may not be broken. Consequently, a secondary dormancy may be induced which is more difficult to break than the original dormancy. If one must err, do it on the long side.

The cold stratification period necessary to break dormancy may last from a few days to several months, depending upon the species, with one to three months being the most common. After stratification, the seeds should be sown promptly before they have a chance to dry out.

**Warm Stratification**

The exposure of seeds to moist, warm conditions at room temperature (65°F) or above is called warm stratification. Sometimes this treatment is necessary for seeds with internal dormancy to facilitate after-ripening of the embryos, in which case it is followed by cold stratification. Occasionally it is used in lieu of the acid treatment for seed coat dormancy. It also may be an intermediate stage in a multiple dormancy treatment. For warm stratification the seeds should be mixed with moist peat moss or moist vermiculite and sealed in a polyethylene bag or a glass jar. Possible places for warm stratification include desk tops, kitchen cupboards, the top of a refrigerator, or perhaps near the furnace-anywhere that stays warm night and day for the prescribed period of time.

**Photochemical Dormancy**

Seeds of some species are light-sensitive and must receive light during germination. The intensity and duration of the light, as received by seed photoreceptors, interact with the available moisture and temperature to control germination. When light and temperature are each partially inhibitory, the effect can be synergistic. The first 36 to 72 hours of germination is the critical period. Photochemical dormancy is most pronounced in freshly harvested seeds and usually disappears naturally with age. For further information on photochemical dormancy, see Cruden (1974).

When germinating seeds indoors in order to break photochemical dormancy, a cool, white fluorescent light source of 75-125 foot candles (750-1250 lux) for eight hours per day can be used (Association of Official Seed Analysts 1981).

Seeds that require light should not be covered when sown but merely watered-in. A covering of glass or plastic over the container will help to maintain a saturated atmosphere around the seeds. A few species must be kept in darkness during the first part of the germination period.

### Germination Temperatures

Though not really a form of dormancy, undesirable temperatures used for germination can be partially or completely inhibitory. Temperature requirements for the germination of seeds of most native California species will be met if the seeds are sown at the proper time of year (see the following section). The range of temperatures required by the seeds of a few species, primarily those of the desert and mountain regions, can be very narrow and specific. If seeds of these plants are sown at the wrong time of year or if temperatures in the area where the seeds are sown are not within the narrow limits for the species, no germination, or at best very poor germination, will occur. For coastal Southern California growers, the greatest problem is encountered with seeds that require high temperatures or wide diurnal temperature fluctuations.

If the recommended daily high-low temperatures are not present naturally, artificial means must be used to produce them, or the propagator will have to be content with poor germination. Where these specific and unusual diurnal temperature fluctuations are necessary, they are noted in the table for the species involved.

## 5. Seed Propagation

### Time to Sow Seeds

At the Santa Barbara Botanic Garden most seeds are sown in small containers in the lath house. When stratification is necessary, it is done prior to the sowing date. Seeds of annuals are sown in late October, herbaceous perennials by July 15, and shrubs and trees by the middle of March. There are several exceptions to the above: seeds of live-forever (Dudleya), buckwheat (Eriogonum), and alum-root (Heuchera) are sown by July l; bush monkeyflower (Diplacus) species are sown in early July with herbaceous perennials; seeds of sea-dahlia (Coreopsis maritima) are sown by September 1for late fall, winter, and early spring flowers; lupine (Lupinus) species seeds, including both bush and herbaceous perennial types, are sown by October 10 for planting out from three-inch pots in late fall for spring flowers; and seeds of Iris, manzanita (Arctostaphylos), and bush poppy (Dendromecon) are sown by October 15. Seeds of desert shrubs and cacti are sown by July 1 in the glasshouse with a minimum temperature of 60°- 65°F; our outdoor night temperatures are too low at this time of year for satisfactory germination. With the above schedule, germination and growing temperatures are favorable; and the timing, in most cases, will produce plants of sufficient size to be ready for late fall planting, when the winter rainy period usually commences.

### Germination Media

There are many suitable media for germinating seeds, and the majority of the California native species have no unusual requirements. A satisfactory general purpose seedbed medium is composed of equal parts of garden loam, builders sand or river sand (not beach sand as it contains too many soluble salts), and moist peat moss, thoroughly mixed together. The soil and sand should be sifted through a sieve of 1/8th inch mesh; the peat moss, through either a 1/4th or 1/2inch mesh screen. Since dry peat moss, as it comes from the bale, absorbs water very slowly, it should be soaked for several hours before use or soaked for a few minutes with constant agitation. The excess moisture should be squeezed out before use. Once peat moss has been wet, it is usually easily remoistened.

To prevent unnecessary seedling losses due to soil-borne diseases and pests, all mixes containing soil or leaf mold should be pasteurized before use by heating to 140°F for 30 minutes to kill insects, their eggs and larvae, and most pathogenic fungi and bacteria. At much above this temperature, beneficial soil microorganisms start to die off. Sterilization requires 180°F for 30 minutes; this temperature kills most organisms and is usually not desirable.

For pasteurization, moistened soil mix should be placed in a shallow pan in an oven at low heat. The temperature of the mix should be raised and held at 140°F, or a little above, for 30 minutes. If the soil mix is not pasteurized or sterilized, young seedlings, particularly very small ones, are likely to succumb to damping-off fungi. In lieu of pasteurization, seeds can be dusted with a fungicide such as "Cooke's Fungicide" or a similar material that specifies on the label that it kills damping-off fungi. Alternatively after sowing, the seedbed can be watered thoroughly with such a fungicide.

A relatively new approach to the problem of pathogenic organisms in containers is the addition to the medium of a beneficial microbial inoculant; this material can be used in place of pasteurization or a fungicide. Even in a sterilized mix its use is beneficial. These microbes have an effect on the soil analogous to the immune system in animals; the beneficial microorganisms, if added in quantity, tend to isolate and neutralize the pathogens. At the Santa Barbara Botanic Garden, in containers smaller than one-gallon, we use a soil-less medium with a microbial inoculant available locally from Material Science Company. There are, no doubt, other similar products available.

Alternatives to media containing soil are the soil-less mixes such as peat moss and perlite (equal parts), vermiculite ( medium or fine, depending on the seed size), or a packaged potting mix. These do not need pasteurization or a microbial inoculant, though the latter is beneficial in a soil-less mix also. When using a medium composed of peat moss, perlite, and /or vermiculite, all of the necessary elements for plant growth must be added since these components are nutrient-free. One way to provide required nutrients is to use a dilute solution of a water-soluble, complete fertilizer with each watering.

To further prevent contamination by pathogenic organisms, used porous containers such as clay pots and wood containers should be cleaned of all foreign material, such as old mix and roots, then soaked 30 minutes or longer in a 1:18 solution of household bleach before re-use. Used plastic containers need to be soaked only for a few minutes. It is important also that the top of the potting bench and all tools, such as trowels, sifters, and wood blocks, be rinsed periodically in a bleach solution or similar sterilant and then kept off the ground to avoid contamination.

**Seed Sowing**

Good seed germination depends largely on proper preparation of the seedbed, depth to which seeds are covered, maintenance of uniform moisture and appropriate temperatures, and, of course, viable seeds. To prepare the seedbed, a container with drainage holes is filled to slightly overflowing with a well-mixed moist medium. The medium is then leveled to the top of the container or about 1/3rd inch below the lip, firmed lightly and uniformly with a flat-surfaced board or large-surfaced object, and watered thoroughly. After watering, the surface of the medium should still be level.

The seeds should be sown in rows about 1.5 inches apart or broadcast evenly on the surface. The sown seeds should then be covered. Milled sphagnum moss (sphagnum moss put through a .25 inch mesh sieve) is very good for this purpose as its slight acidity helps to discourage damping off. Washed sand or seedbed mix may also be used as a seed cover. After the seeds have been sown and covered, the container should be lightly sprinkled again with a fine spray of water and placed in a sheltered location out of direct sunlight. A beneficial microbial inoculant can be used for these waterings and also for the initial moistening. The depth of sowing or thickness of the seed covering is especially important as seeds sown too deeply will not produce seedlings. Such seeds may start to germinate, but the developing shoots will die before reaching the light at the surface of the seedbed. A general rule is to cover a seed to a depth equal to one to two times its smallest diameter.

Very fine seeds, such as those of alum root (Heuchera), bush-anemone (Carpenteria), or monkeyflower (Mimulus and Diplacus), should be covered just slightly with milled sphagnum moss or watered-in without a covering. It is desirable to label each seeded container with the name of the species and the date sown.

For protection against rodents, snails, birds, and drying out, the container should then be enclosed in a polyethylene bag or covered with a piece of polyethylene film, with a single sheet of newspaper on top to prevent heat build-up. During the germination period, the surface of the medium must be kept moist. As the seeds start to germinate, the newspaper and plastic should be removed; better results may be obtained by leaving very small seedlings completely enclosed in plastic until germination is complete. However, the plastic should not touch the seed leaves. If the weather is unusually hot and dry, it is best to acclimatize very small seedlings gradually by poking a few holes in the plastic each day or two and then removing the plastic entirely. A glass cover can be used instead of plastic. Germination for most species takes one to four weeks.

**Transplanting**

Seedlings should be spotted-off or transplanted into flats, trays, or small pots (liners) as soon as they are large enough to handle. Species with large seed leaves, such as sugar bush ( Rhus ovata), should be spotted-off to liners at the two-leaf stage, but those with very small seed leaves, such as monkeyflower ( Mimulus and Diplacus species), should not be transplanted until the six- or eight-leaf stage. Since seedlings are bare-rooted in spotting off, care must be taken to protect the tender roots from drying out and from excessive breakage; also when handling, care must be taken not to crush the fragile stems. Young plants in seed flats are sometimes spaced very close together and can be difficult to separate. To facilitate separation, a small group of seedlings may be lifted out with a putty knife or a fork and dropped to the potting bench from a height of three to four inches. Seedlings should be planted at the same depth that they were in the seed flat, or slightly lower. The medium can be the same as that used for germination and must always be moist when used. Again, a soil medium should be pasteurized with heat or moistened with a microbial inoculant.

The young seedlings should be transplanted a second time when their roots begin to fill the soil mass in the container. Annuals should be moved directly into the open ground at this time. Herbaceous perennial seedlings may be planted out also, but receive less setback and have a better chance if they are transplanted to four-inch pots first and later moved to the open ground. Shrub and tree seedlings should be spotted-off from the seedbed to three inch pots, then to one-gallon cans, and finally to the garden. It may be more appropriate for trees to be moved from one-gallon to five-gallon containers and then to the garden. The five-gallon stage normally takes one or two growing seasons.

Seeds of tap-rooted tree species should be individually sown in deep containers such as quart milk cartons. If the bottom of the container is removed and the container set on hardware cloth covered with one thickness of newspaper or a screen and placed three to six inches above the ground, the tap roots will prune themselves, because the root tips will die when they reach dry air. Seedlings can be root pruned manually by snipping no more than 1/16th – 1/8th inch off the tip of the root; the thumb nail does a fine job. Another method of handling the seeds of tap-rooted species, particularly those of oaks, is to place the seeds in a polyethylene bag containing moist peat moss. Kept at room temperature, the primary roots will soon become visible. When a seed has a visible root, it should be removed from the bag, root-pruned as noted above, and planted. Again, the recommended planting sequence is from a quart milk carton or a one-gallon can to the field, or from a quart milk carton to a five-gallon can and to the field. Four by 14-inch plastic pots (2.5-inch diameter bottom hole) set on hardware cloth are excellent for propagation of tap-rooted species.

The seeds can be sown directly; the seedlings can be grown for a season and then planted out without any transplanting at all. This size container is much more appropriate than a one-gallon can for tap-rooted tree species. Slightly shorter containers would be necessary if plants in five-gallon containers are required. Regardless of how the tap-rooted species are handled, it is imperative to transplant their seedlings before the roots circle the container, particularly at the liner stage (3" pot). Generally speaking, pot-bound trees and shrubs become culls instead of beautiful mature specimen plants.

Although the same medium used for the seed flats and liners can be used for one-gallon or larger containers, a coarser mix is also satisfactory. A light, well-drained, pasteurized, or microbial-inoculated mix of sandy loam and peat moss or wood shavings serves quite well. If the soil is too coarse, it should be sifted through a ½ inch mesh screen. Care should be taken not to overwater newly potted or canned plants. In regions away from the immediate coast, some protection from full summer sun is needed for container plants. This protection can be critical during occasional heat waves when root systems of container-grown plants can become overheated, killing the plants. Thirty percent shade saran is adequate.

Most native plants respond well to light applications of commercial fertilizer and will require some fertilization while in containers.

**Field Sowing of Annual Wildflowers**

Although seeds of California wildflowers can be started in flats like those for bedding plants, better results are usually obtained by sowing them directly on the open ground, or with very small-seeded types, several seeds to a three-inch peat or paper pot. The seedlings, when large enough, can be thinned and later planted out in the garden with practically no root disturbance. For field sowing, the moistened soil should be cultivated and leveled, the seeds broadcast, and the area kept moist throughout the germination period. In the case of large-seeded species such as sea-dahlia (Coreopsis maritima) and some lupines (Lupinus), the seeds should be raked in lightly after sowing and before watering. If a mixture of large and small seeds is used, the large seeds should be separated out, sown and lightly raked in, then the small seeds broadcast on top. Following this procedure, the seeds can be sown as late as early December with good results.

For large areas where no seedbed preparation is made, the seeds should be broadcast just before the first rains in the fall. This enables the wildflower seeds to germinate with and to compete with any annual vegetation. A few of the tougher annuals like California poppy (Eschscholzia califomica), tidy tips (Layia platyglossa), and Clarkia may give good results when sown under these conditions; however, wildflower seed germination is always better in a well-prepared seedbed.

## 6. Recommended Seed Treatments for Some Native California Plants

The (seed treatments integrated into the CNPS Calscape plant pages) is a compilation of the original publication published in 1964 plus information from records of subsequent propagation at the Santa Barbara Botanic Garden and also additional data from other sources.

It should be emphasized that the suggested seed treatments are not necessarily the only ones that will prove satisfactory. For problem species (those whose seeds are difficult to germinate), there may be more than one treatment listed. For example, if you refer to Ceanothus cuneatus (buck brush) in the table, two treatments are listed. "Hot water and three months stratification" results in significantly better germination than the chemical treatment but leaves the seeds in an unusable condition if they are to be sown with mechanical equipment. After stratification, the seeds are rather soft and moist, some radicals may be showing, and the seeds should not be dried out before sowing. With the chemical treatment, no germination will have started; the seeds can be dried out before sowing, need not be sown immediately, and can be sown with mechanical equipment. The chemical treatment also has the advantage of being quicker, even though a lower percentage of germination usually results.

Stratification, as used in these recommendations, refers to cold stratification unless stated otherwise; diurnal fluctuation refers to temperature. Scarification, if practical, can be substituted for the hot water treatment. The seeds of the majority of the native species germinate promptly without pretreatment. Since this is true of most annuals, only those annuals known to require special treatment and for which a satisfactory treatment is known are included in this table. Dormancy is highly variable, sometimes even in seeds from the same plant harvested in the same year, hence an entry like that for incense cedar (Calocedrus decurrens ) 1-2 months stratification; no treatment may give good germination." For more information on the variability aspect of seed dormancy, see Gutterman (1980-1981). Some seeds germinate without pretreatment if they are sown when fresh (as soon as ripe, or even when slightly green), but become dormant as they dry out; in such cases, stored seeds require treatment while fresh seeds do not. Some seeds of other species may normally have low viability.

Since seeds are living protoplasm and subject to many environmental variables, the seed treatments suggested here may not always give consistent results, particularly for different seed batches harvested from different localities. The recommendations will, however, serve as a guide for the plant propagator. If a particular problem species or perhaps even the genus is not listed here, for possible direction, see Atwater (1980). Plant nomenclature follows Munz and Keck (1973), and Munz (1974) with selected changes in Kartesz and Kartesz (1980).