Plant Propagation

Adapted from Texas Master Gardener Manual
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Asexual (or Vegetative) Plant Propagation

Plant propagation is the process of multiplying the numbers of a plant, perpetuating a species, or maintaining a plant's youthfulness. There are two types of propagation—asexual and sexual. Sexual plant propagation involves seeds (or spores) and takes advantage of meiosis (reductive cell division) and recombination of genetic material. Offspring contain genetic material from both the maternal and paternal parent. Asexual propagation of a plant's vegetative parts (roots, stems, or leaves) only involves mitosis (nonreductive cell division) and no genetic recombination. Offspring are genetically identical to the maternal (only) parent. Part of a single parent plant is made to regenerate itself into a new plant. There are several advantages to propagating plants asexually. It may be the easiest and fastest way to propagate some plant species. In addition, it may be the only way to perpetuate some cultivars, and it bypasses the juvenile characteristics of certain species. The Kieffer pear and the Peace rose are two examples of clones that have been asexually propagated for many years.

The major methods of asexual propagation are cuttings, layering, grafting, and budding. Cuttings involve rooting a severed piece of the parent plant, while layering involves rooting a part of the parent and then severing it. Budding and grafting involve joining two plant parts from different varieties.

Cuttings

Many types of plants, both woody and herbaceous, frequently are propagated by cuttings (fig. 1). A cutting is a vegetative plant part that is severed from the parent plant in order to regenerate itself, thereby forming a whole new plant.

Take cuttings with a sharp knife or razor blade to reduce injury to the parent plant. Dip the cutting tool in rubbing alcohol or a mixture of one part bleach and nine parts water to prevent transmitting diseases from infected plant parts to healthy ones. Remove flowers and flower buds from cuttings to allow the cutting to use its energy and stored carbohydrates for root and shoot formation rather than for fruit and seed production. To hasten rooting, increase the number of roots. To obtain uniform rooting, except with soft fleshy stems, use a rooting hormone that preferably contains a fungicide. Prevent possible contamination of the entire supply of rooting hormone by pouring some in a separate container for dipping cuttings.

Insert cuttings into a rooting medium, such as coarse sand, vermiculite, soil, water, or a mixture of peat and perlite. Choose the correct rooting medium to get optimum rooting in the shortest time. In general, the rooting medium should be sterile and low in fertility. It should also drain well enough to provide oxygen and retain enough moisture to prevent water stress. Moisten the medium before inserting cuttings and keep it evenly moist while cuttings are rooting and forming new shoots.

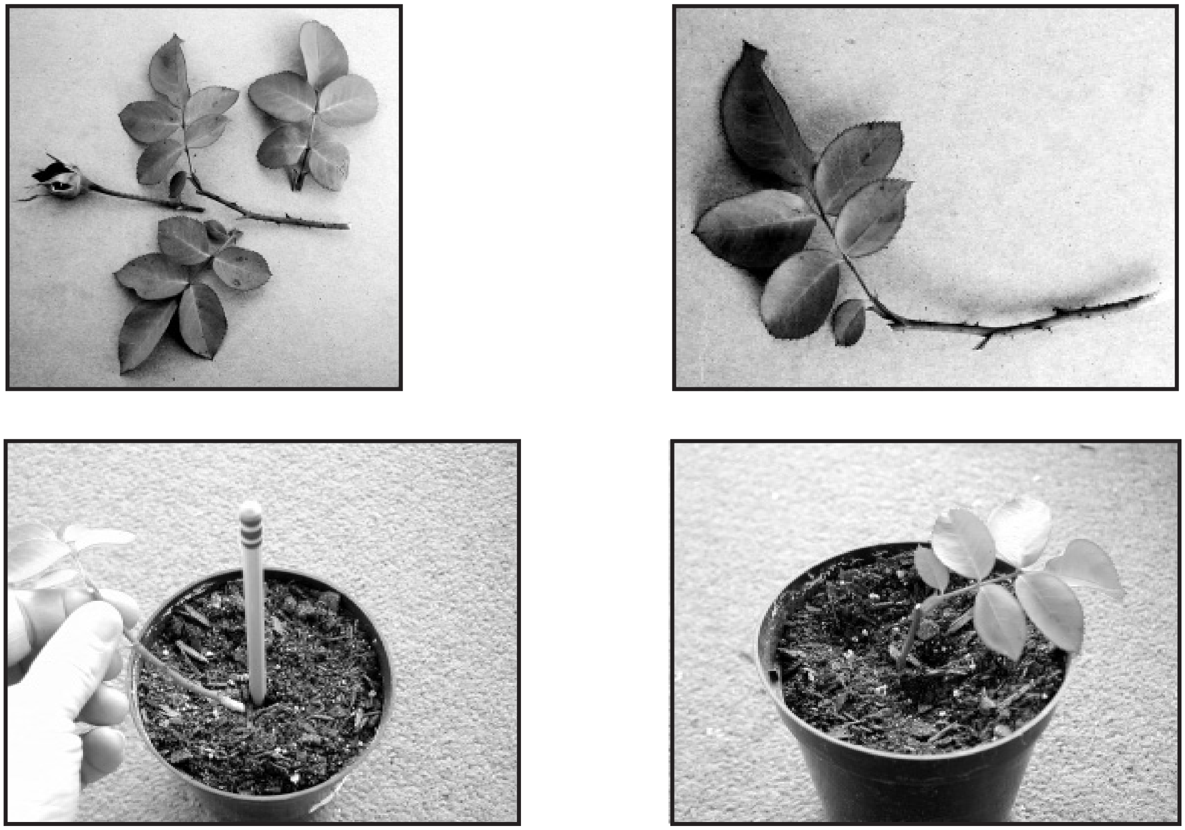
Place stem and leaf cuttings in bright but indirect light. Root cuttings can be kept in the dark until new shoots appear.

Stem Cuttings

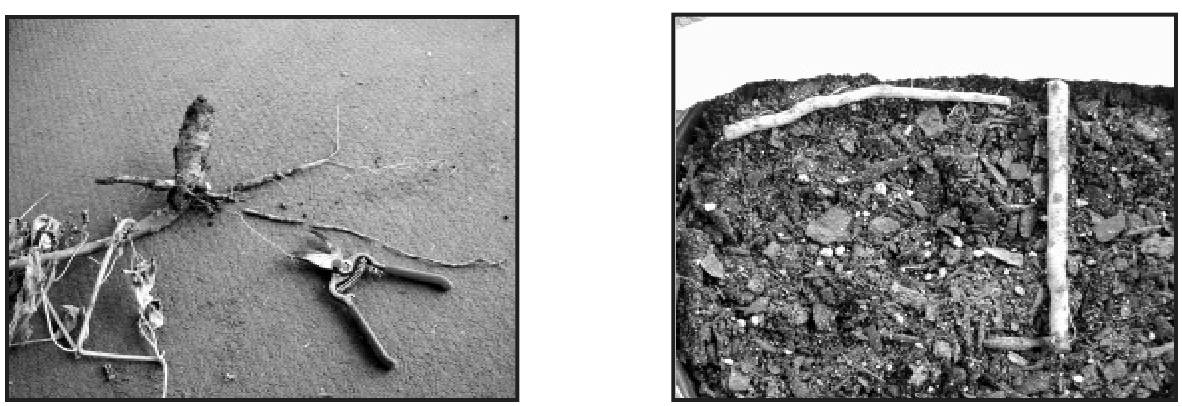
Numerous plant species are propagated by stem cuttings (fig. 1). While some can be taken at any time, stem cuttings of many woody plants must be taken in the fall or in the dormant season.

Tip Cuttings

Detach a 2- to 6-inch piece of stem, including the terminal bud. Make the cut just below a node. Remove lower leaves that would touch or be below the medium. Dip the stem in rooting hormone if desired. Gently tap the end of the cutting to remove excess hormone. Insert the cutting deeply enough into the media to support itself. At least one node must be below the surface.



Stem cuttings



Root cuttings

Figure 1. Examples of stem and root cuttings.

Medial Cuttings

Make the first cut just above a node and the second cut just above a node 2 to 6 inches down the stem. Prepare and insert the cutting as you would a tip cutting. Be sure to position the cutting right side up. Axial buds always are above leaves.

Cane Cuttings

Cut canelike stems into sections containing one or two eyes or nodes. Dust ends with fungicide or activated charcoal. Allow the canes to dry for several hours. Lay horizontally with about half of the cutting below the media surface and the eye facing upward. Cane cuttings usually are potted when roots and new shoots appear, but new shoots from dracaena and croton often are cut off and rerooted in sand.

Single Eye

The eye refers to the node. This is used for plants with alternate leaves when space or stock material are limited. Cut the stem about 1/2 inch above and 1/2 inch below a node. Place the cutting horizontally or vertically in the medium.

Double Eye

This is used for plants with opposite leaves when space or stock material is limited. Cut the stem about 1/2 inch above and 1/2 inch below the same node. Insert the cutting vertically into the medium, with the node just touching the surface.

Heel Cutting

This is an efficient method for stock material with woody stems. Make a shield-shaped cut about halfway through the wood around a leaf and axial bud. Insert the shield horizontally into the medium.

Leaf Cuttings

Leaf cuttings are used almost exclusively for a few indoor plants. Leaves of most plants will either produce a few roots but no plant, or the roots will just decay.

Whole Leaf with Petiole

Detach the leaf and 1/2 to 1 1/2 inches of petiole. Insert the lower end of the petiole into the medium. One or more new plants will form at the petiole's base. The leaf may be severed from the new plants when they have grown their own roots. The petiole can be reused.

Whole Leaf without Petiole

This is used for plants with sessile or petioleless leaves. Insert the cutting vertically into the medium. A new plant will form from the axillary bud. The leaf may be removed when the new plant has its own roots.

Split Vein

Detach a leaf from the stock plant. Slit its veins on the lower leaf surface. Lay the cutting, lower side down, on the medium. New plants will form at each cut. If the leaf tends to curl up, hold it in place by covering the margins with the rooting medium.

Leaf Sections

This method is frequently used with snake plant and fibrous rooted begonias. Cut begonia leaves into wedges with at least one vein. Lay leaves flat on the medium. A new plant will grow at the vein. Cut snake plant leaves into 2-inch sections. Consistently make the lower cut slanted and the upper cut straight so you can tell which is the top. Insert the cutting vertically. Roots will form fairly soon, and eventually a new plant will appear at the base of the cutting. These and other succulent cuttings will rot if kept too moist.

Root Cuttings

Root cuttings usually are taken from 2- to 3-year-old plants, when they have a large carbohydrate supply in their dormant season. Root cuttings of some species produce new shoots that form their own root systems, while root cuttings of other plants develop root systems before producing new shoots (fig. 1).

Plants with Large Roots

First, make a straight top cut; then make a slanted cut 2 to 6 inches below the first cut. Store about 3 weeks in moist sawdust, peat moss, or sand at 40° F. Remove from storage. Insert the cutting vertically, with the top approximately level with the rooting medium surface. This method often is done outdoors.

Plants with Small Roots

Take 1- to 2-inch sections of roots. Insert the cuttings horizontally about 1/2 inch below the medium surface. This method usually is done indoors or in a hotbed.

Layering

Stems still attached to their parent plants may form roots where they touch a rooting medium. Severed from the parent plant, the rooted stem becomes a new plant. This vegetative propagation method, called layering, has a high success rate, because it prevents the water stress and carbohydrate shortage that sometimes plague cuttings (fig. 2).

Some plants layer themselves naturally; sometimes plant propagators assist the process. Layering is enhanced by girdling the stem where it is bent, by wounding one side of the stem, or by bending it very sharply. The rooting medium always should provide aeration and a constant moisture supply.

Tip Layering

Dig a hole 3 to 4 inches deep (fig. 2). Insert the shoot tip and cover it with soil. The tip grows downward first, then bends sharply and grows upward. Roots form at the bend, and the recurved tip becomes a new plant. Remove the tip layer and plant it in early spring or late fall. This method is successful with purple and black raspberries and trailing blackberries.

Simple Layering

Bend the stem to the ground. Cover part of it with soil, leaving the last 6 to 12 inches exposed (fig. 2). Bend the tip into a vertical position and stake in place. The sharp bend often will induce rooting, but wounding the lower side of the branch or loosening the bark by twisting the stem may help. This method is successful with rhododendron and honeysuckle.

Compound Layering

This method works for plants with flexible stems (fig. 2). Bend the stem to the rooting medium as with simple layering, but alternately cover and expose stem sections. Wound the lower side of the stem sections to be covered. This method is successful with heart-leaf philodendron and pothos.

Mound (Stool) Layering

Cut the plant back to 1 inch above the ground in the dormant season (fig. 2). Mound soil over the emerging shoots in spring to enhance their rooting. This method is successful with gooseberries and apple rootstocks.

Air Layering

Air layering is used to propagate some indoor plants with thick stems or to rejuvenate them when they become leggy (fig. 2). Slit the stem just below a node. Pry the slit open with a toothpick. Surround the wound with wet, unmilled sphagnum moss. Wrap plastic or foil around the sphagnum moss and tie it in place. When roots pervade the moss, cut the plant off below the root ball. Use this method with dumbcane and rubber tree, for example.

The following propagation methods can all be considered types of layering, because the new plants form before they are detached from their parent plants.

Stolons and Runners

A stolon is a horizontal, often fleshy stem that can root and then produce new shoots where it touches the medium (fig. 2). A runner is a slender stem that originates in a leaf axil and grows along the ground or downward from a hanging basket, producing a new plant at its tip. Plants that produce stolons or runners are propagated by severing the new plants from their parent stems. Plantlets at the tips of runners may be rooted while still attached to the parent, or they can be detached and placed in a rooting medium. This method can be used with strawberry and spider plants, for example.

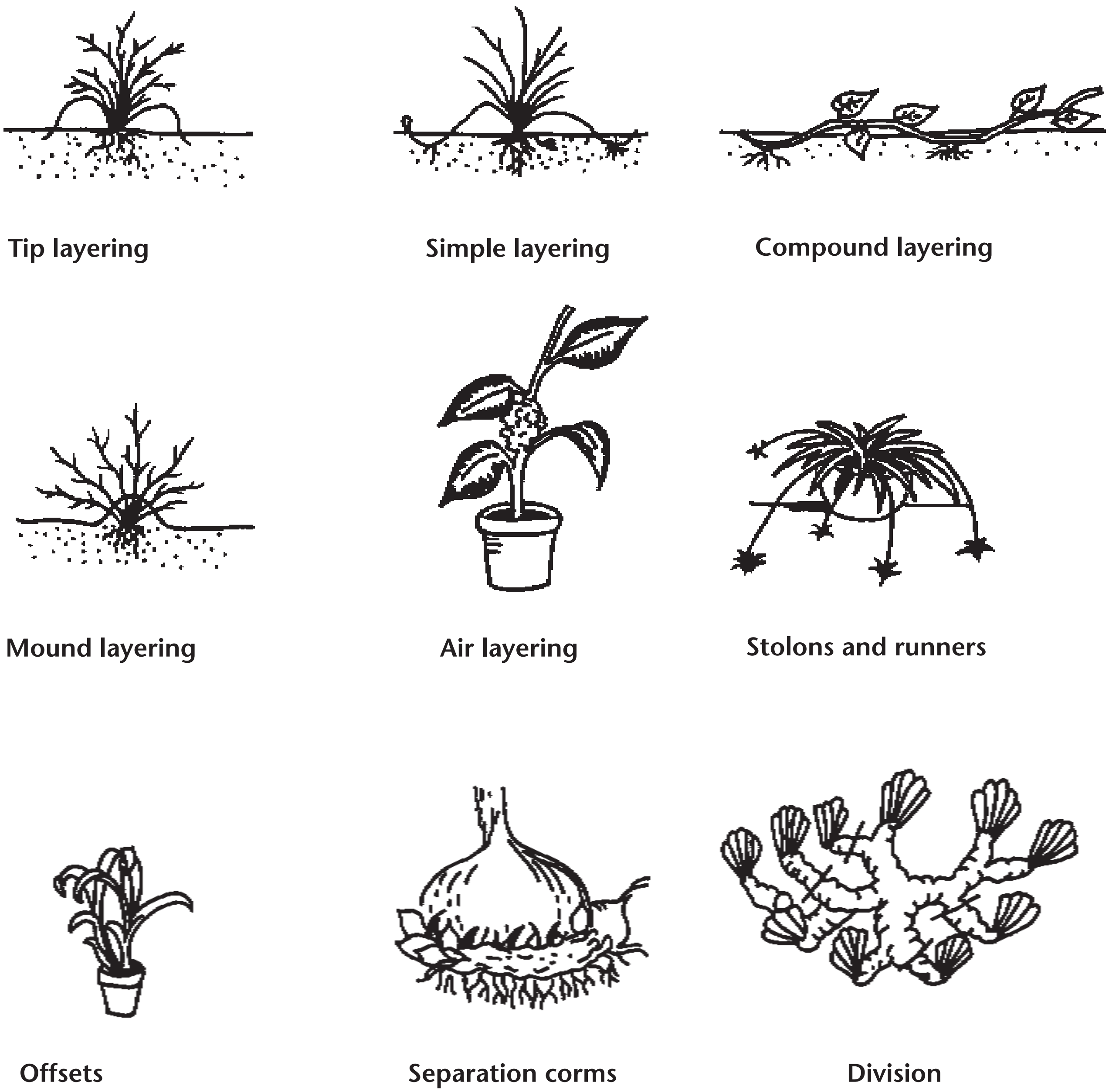


Figure 2. Types of layering, layering, division, and separation.

Offsets

Plants with a rosetted stem often reproduce by forming new shoots at their base or in leaf axils (fig. 2). Sever the new shoots from the parent plant after they have developed their own root system. Unrooted offsets of some species may be removed and placed in a rooting medium. Some of these must be cut off, while others may be simply lifted off of the parent stem. This method can be used with date palm, haworthia, bromeliads, and many cacti.

Separation

Separation is a form of propagation by which plants that produce bulbs or corms multiply (fig. 2).

Bulbs

New bulbs form beside the original bulb. Separate these bulb clumps every 3 to 5 years for largest blooms and to increase bulb population (fig. 2). Dig up the clump after the leaves have withered. Gently pull the bulbs apart and replant them immediately, so their roots can begin to develop. Small new bulbs may not flower for 2 or 3 years, but large ones should bloom the first year. Use this method with tulip and narcissus, for example.

Corms

A large, new corm forms on top of the old corm, and tiny cormels form around the large corm (fig. 2). After the leaves wither, dig up the corms and allow them to dry in indirect light for 2 or 3 weeks. Remove the cormels, then gently separate the new corm from the old corm. Dust all new corms with a fungicide and store in a cool place until planting time. Use this method with crocus and gladiolus, for example.

Division

Plants with more than one rooted crown may be divided and the crowns planted separately (fig. 2). If the stems are not joined, gently pull the plants apart. If the crowns are united by horizontal stems, cut the stems and roots with a sharp knife to minimize injury. Divisions of some outdoor plants should be dusted with a fungicide before they are replanted. Try this method with snake plant, iris, prayer plant and daylilies.

Grafting

Grafting and budding are methods of asexual plant propagation that join plant parts, so they will grow as one plant (fig. 3). These techniques are used to propagate cultivars that will not root well as cuttings or whose own root systems are inadequate. One or more new cultivars can be added to existing fruit and nut trees by grafting or budding.

The plant portion of the cultivar that is to be propagated is called the scion. It consists of a piece of shoot with dormant buds that produce the stem and branches. The rootstock, or stock, provides the new plant's root system and sometimes the lower part of the stem. The cambium is a layer of cells located between the stem's wood and bark from which new bark and wood cells originate.

The following four conditions must be met for grafting to be successful: the scion and rootstock must be compatible; each must be at the proper physiological stage; the cambial layers of the scion and stock must meet; and the graft union must be kept moist until the wound has healed.

Cleft Grafting

Cleft grafting often is used to change the cultivar of a shoot or young tree, usually a seedling (fig. 3). It is especially successful if done in the early spring. Collect scion pieces 3 to 5 inches long that have one or two buds. Cut the limb or small tree trunk so it can be reworked perpendicular to its length. Make a 2-inch vertical cut through the previous cut's center, being careful not to tear the bark. Keep this cut wedged open. Cut the lower end of each scion piece into a wedge. Prepare two scion pieces 3 to 4 inches long and insert the scions at the outer edges of the cut in the stock. Tilt the top of the scion slightly outward and the bottom slightly inward to be sure the cambial layers of the scion and stock touch. Remove the wedge propping the slit open and cover all cut surfaces with grafting wax.

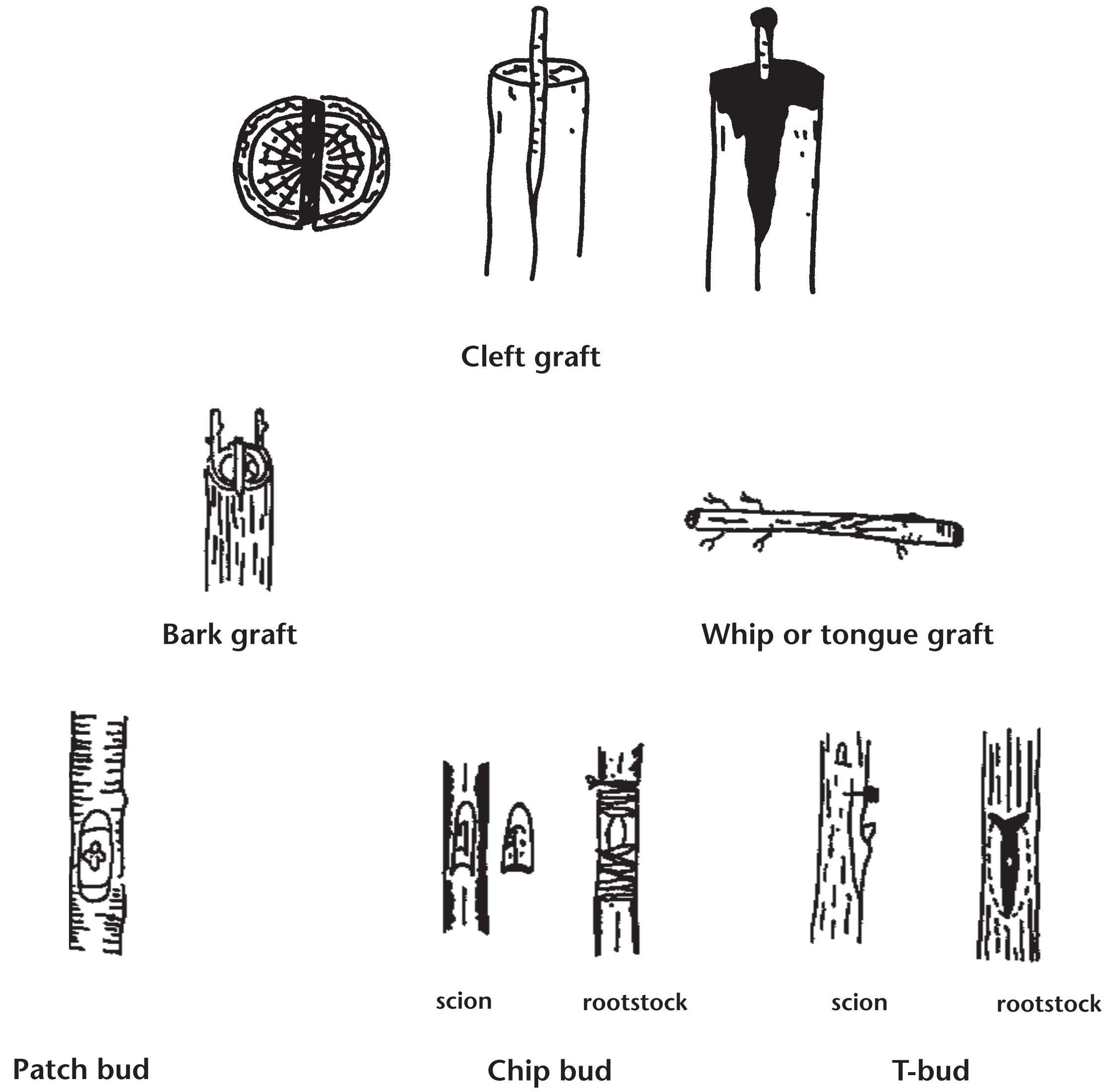


Figure 3. Types of grafting.

Bark Grafting

Unlike most grafting methods, bark grafting can be used on large limbs, although bark grafts often are infected before the wound can completely heal (fig. 3). Collect scion wood 3/8 to 1/2 inches in diameter when the plant is dormant; store the wood wrapped in moist paper in a plastic bag in the refrigerator. Saw off the rootstock's limb or trunk at a right angle to itself. In the spring, when the bark is easy to separate from the wood (known as slipping), make a 1/2-inch diagonal cut on one side of the scion and a 1 1/2-inch diagonal cut on the other side. Leave two buds above the longer cut. Make a cut a little wider than the scion through the stock's bark and remove the top third of the bark from this cut. Insert the scion with the longer cut against the wood and nail the graft in place with flat-headed wire nails. Cover all wounds with aluminum foil and clear polyethylene plastic.

Whip or Tongue Grafting

This method often is used for material 1/4 to 1/2 inch in diameter (fig. 3). The scion and rootstock usually are the same diameter, but the scion may be narrower than the stock. This strong graft heals quickly and provides excellent cambial contact. Make a single 2 1/2-inch sloping cut at the top of the rootstock and a matching cut on the bottom of the scion. On the cut surface, slice downward into the stock and upward into the scion so the pieces will interlock. Fit the pieces together, then tie and wax the union.

Care of the Graft

Very little success in grafting will occur unless proper care is maintained for the following year or two. If a binding material, such as strong cord or nursery tape, is used on the graft, it must be cut shortly after growth starts in order to prevent girdling and death. Rubber budding strips have some advantages over other materials, because they expand with growth, do not usually need to be cut as they deteriorate, and break after a short time. It also is an excellent idea to inspect the grafts after 2 or 3 weeks to see if the wax has cracked. If necessary, rewax the exposed areas. After this, the union probably will be strong enough, and no more waxing will be necessary.

Limbs of the old variety that are not chosen for grafting should be cut back at the time of grafting. The total leaf surface of the old variety should be reduced gradually as the new one increases, until the new variety has completely taken over at the end of 1 or 2 years. Complete removal of all the old variety's limbs at the time of grafting increases the shock to the tree and causes excessive suckering. In addition, the scions may grow too fast, making them susceptible to wind damage.

Budding

Budding, or bud grafting, is the union of one bud and a small piece of bark from the scion with a rootstock (fig. 3). It is especially useful when scion material is limited. It also is faster and forms a stronger union than grafting.

Patch Budding

Plants with thick bark should be patch-budded (fig. 3). This is done while the plants are actively growing, so their bark slips easily. Remove a rectangular piece of bark from the rootstock. Cover this wound with a bud and matching piece of bark from the scion. If the rootstock's bark is thicker than that of the scion, pare it down to meet the thinner bark so that when the union is wrapped the patch will be held firmly in place.

Chip Budding

This budding method can be used when the bark is not slipping (fig. 3). Slice downward into the rootstock at a 45° angle through 1/4 inch of the wood. Make a second cut about 1 inch long upward from the first cut. Remove a bud and attending chip of bark and wood from the scion, shaped so that it fits the rootstock wound. Fit the bud chip to the stock, and wrap the union.

T-Budding

This is the most commonly used budding technique (fig. 3). When the bark is slipping, make a vertical cut (same axis as the rootstock) through the rootstock's bark while avoiding any buds on the stock. Make a horizontal cut at the top of the vertical cut (in a T shape) and loosen the bark by twisting the knife at the intersection. Remove a shield-shaped piece of the scion, including a bud, some bark, and a thin section of wood. Push the shield under the loosened stock bark, and wrap the union, leaving the bud exposed.

Care of Buds

Place the bud in the stock in August. Force the bud to develop the following spring by cutting the stock off 3 to 4 inches above the bud. The new shoot may be tied to the resulting stub to prevent damage from wind. After the shoot has made a strong union with the stock, cut the stub off close to the budded area.

Mini Greenhouse/Propagation Tent for the Home Gardener

The main problem in propagation is ensuring the survival of the propagated material until it establishes a new young plant. An environment that allows for minimum water loss from the plant material, adequate light for photosynthesis, and good soil drainage is important. Commercially, many kinds of propagation units and related equipment are available for propagation on a large scale. However, for the home gardener these options are not physically or economically feasible. The home gardener can be successful in propagating many plant materials in a homemade propagation tent.

A homemade propagation tent is a cheap and simple arrangement that provides a sufficiently effective closed environment for easily propagated plants. Fill a pot, tray or shallow pan with the potting medium. Fill the container with cuttings and cover with a polyethylene bag supported at either end by a looped wire or dowel rod. This will prevent the bag from touching the cuttings. Seal the end of the bag with a rubber band. This technique makes a very effective mini greenhouse that allows the home gardener to be very successful with asexual propagation of many plant materials.

Sexual Plant Propagation

Plants also can be propagated using sexual propagation, which involves the union of the pollen from the male with the egg from the female in order to produce a seed. The seed is made up of the following three parts: the outer seed coat, which protects the seed; the endosperm, which is a food reserve; and the embryo, which is the young plant itself. When a seed matures and is put in a favorable environment, it will germinate and begin growing actively. This radicle is the first part of the seedling to emerge from the seed. It will develop into the primary root from which root hairs and lateral roots will grow. The portion of the seedling between the radicle and the first leaflike structure is called the hyopcotyl. The seed leaves (cotyledons) encase the embryo and are usually different in shape from leaves produced by the mature plant. Plants producing one cotyledon fall into the group of monocotyledons. Plants producing two seed leaves are called dicotyledons.

Seed Germination

To obtain quality plants, start with good quality seed from a reliable dealer. Choose varieties adapted to your area and make selections based on desired size, color, and growth habit. Many new vegetable and flower varieties are hybrids, which may cost a little more than open-pollinated types. However, hybrid plants usually have more vigor, more uniformity, and better production than nonhybrids. Some hybrids also have specific disease resistance or other unique cultural characteristics.

It is important to purchase good seeds. Although some seed will keep for several years if stored properly, it is advisable to purchase only enough seed for use in the current year. Storage reduces seed viability and vigor. Viability is a measure of the percentage of live seeds. During storage, some seeds die, others lose vigor and will not germinate as rapidly as new seeds. Good seed should not contain weeds or seeds of any other crop and should have little debris. Printing on the seed packet usually indicates essential information about the variety, the year for which the seeds were packaged, percentage of germination to be expected, and notes about any chemical seed treatment. If seeds are obtained well in advance of the actual sowing date or if they are stored as surplus, keep them in a cool, dry place. Laminated foil packets help ensure dry storage. Paper packets are best kept in tightly closed jars or containers and maintained at approximately 40° F in low humidity.

Some gardeners save seed from their own gardens. However, this seed is the result of random pollination by insects or other natural agents and may not produce plants typical of the parents. This is especially true of the many hybrid varieties.

Most seed companies take great care to handle seed properly. Generally, 65 to 80 percent of the seed sown will germinate. From the germinated seed, expect about 60 to 75 percent to produce satisfactory, vigorous and sturdy seedlings.

Factors Affecting Germination

Germination of seeds is controlled by either external environmental factors or by internal dormancy factors. Of course, if the seed is dead it will not germinate. Four environmental factors affect germination, including water, oxygen, light, and heat. A quiescent seed is a living seed capable of germinating as soon as the external environmental conditions are proper. Dormant seeds contain internal factors that delay germination even when the external environment is proper for germination.

Environmental Factors Affecting Germination

Water. The first step in the germination process is the absorption of water. Even though seeds have great absorbing power—due to the nature of the seed coat—the amount of available water in the germination medium affects the water uptake. An adequate, continuous supply of water is important to ensure germination. Once the germination process begins, a dry period will cause the embryo to die.

Light. The light reaction is a complex process that may either stimulate or inhibit seed germination. Examples of plants requiring light for seed germination are ageratum, begonia, browallia, impatiens, lettuce, and petunia. Conversely, calendula, centaurea, pansy, annual phlox, verbena, and vinca germinate best in the dark. Other plants are not specific at all. Seed catalogs and seed packets often list germination or cultural tips for individual varieties. When sowing seed that requires light, do as nature does and leave the seed on the soil surface. If the seed is covered at all, use a light layer of fine peat moss or fine vermiculite. If not applied too heavily, these materials will permit some light to reach the seed and will not limit germination. When starting seed in the home, suspend fluorescent lights 6 to 12 inches above the seed for 16 hours a day.

Oxygen. Respiration takes place in all viable seed. In nongerminating seed, respiration is low but some oxygen is required. The respiration rate increases during germination. Therefore, the medium in which the seed is placed should be loose and well-aerated. If the oxygen supply during germination is limited or reduced, germination can be severely retarded or inhibited.

Heat. Favorable temperature is another important requirement for germination. It not only affects the germination percentage but also the germination rate. Some seeds will germinate over a wide range of temperatures, while others require a narrow range. Many seeds have minimum, maximum, and optimum temperatures for germination. For example, tomato seed has a minimum germination temperature of 50° F, a maximum temperature of 95° F and an optimum germination temperature of about 80° F. When germination temperatures are listed, they are usually the optimum temperatures unless otherwise specified. Generally, 65° to 75° F is best for most plants. Sometimes, germination flats need to be placed in special chambers or on radiators, heating cables, or heating mats to maintain optimum temperature. The importance of maintaining proper medium temperature to achieve maximum germination percentages cannot be overemphasized.

Germination will begin when certain internal requirements are met. A seed must have a mature embryo, contain a large enough endosperm to sustain the embryo during germination, and contain sufficient hormones or auxins to initiate the process.

Methods of Breaking Dormancy

One of the functions of dormancy is to prevent a seed from germinating at the wrong time of year. Though the seeds ripen when conditions are proper for germination, those conditions may not persist long enough to allow the plant to survive. Such is the case for seeds that ripen in the autumn, they must wait for spring to germinate. Internal dormancy factors are needed to delay germination until spring. Plants native to arid climates have internal factors to delay germination until there is sufficient soil moisture. In some trees and shrubs, dormancy is difficult to break, even when the environment is ideal. Various treatments are performed on the seed to break dormancy and begin germination.

Seed Scarification

Some seeds are dormant because their coverings prevent the entry of water and oxygen to the embryo. They require scarification, which involves breaking, scratching, or softening the seed coat so that water can enter and germination can begin. There are several methods of scarifying seeds. In acid scarification, seeds are put in a glass container and covered with concentrated sulfuric acid at about twice the volume of the seeds. The seeds are stirred gently and allowed to soak from 10 minutes to several hours, depending on the hardness of the seed coat. When the seed coats become thin, the seeds can be removed, washed, and planted.

Another scarification method is mechanical. Seeds are filed with a metal file, rubbed with sandpaper, or cracked with a hammer to weaken the seed coat prior to planting. Seed scarification also can be accomplished using hot water (170° to 212° F); the seeds are left to soak in the water as it cools for 12 to 24 hours before planting. A fourth method involves storing seeds in a nonsterile, warm, damp container where the seed coat will be broken down by decay over several months.

Seed Stratification

Seeds of some fall-ripening trees and shrubs of the temperate zone will not germinate unless chilled underground as they overwinter. This so-called "after ripening" may be artificially accomplished through stratification.

The following stratification procedure usually is successful. Fill a clay pot with sand or vermiculite to about 1 inch from the top. Place the seeds on top of the medium and cover with 1/2 inch of sand or vermiculite. Wet the medium thoroughly and allow excess water to drain through the hole in the pot. Place the pot containing the moist medium and seeds in a plastic bag and close the bag using a twist tie or rubber band. Place the bag in a refrigerator. Periodically check to make sure the medium is moist but not wet; additional water probably will not be necessary. After 10 to 12 weeks, remove the bag from the refrigerator. Take the pot out and set it in a warm place in the house. Water often enough to keep the medium moist. Soon the seedlings should emerge. When the young plants are about 3 inches tall, transplant them into larger pots until time for setting outside.

Another stratification procedure that usually is successful uses sphagnum moss or peat moss. Thoroughly wet the moss and squeeze out excess water. Mix seed with the sphagnum or peat and place in a plastic bag. Use a twist tie or rubber band to secure the top and put the bag in a refrigerator. Temperatures ranging from 35° to 45° F (2° to 7° C) are effective, and most refrigerators operate in this range. Check the bag periodically. If there is condensation on the inside of the bag, the process probably will succeed. After 10 to 12 weeks, remove the bag from the refrigerator and plant the seeds in pots to germinate and grow. Handle the seeds carefully. Small roots and shoots often emerge at the end of the stratification period and care must be taken not to break them off.

Seeds of most fruit and nut trees can be germinated successfully using these procedures. Peach seeds should be removed from the hard pit. Care must be taken when cracking the pits as any injury to the seed itself can provide an entrance for disease organisms.

Leaching

Some seeds contain chemical inhibitors within the seed or seed coverings. These inhibitors serve as rain gauges that prevent germination until there is adequate precipitation for germination. This type of dormancy is most common in plants from arid regions.

To artificially overcome chemical dormancy, soak the seeds in running water or in water that is changed frequently to leach the chemicals from the seeds. Once completed, plant the seed immediately, because the moisture has hydrated the embryos that are ready to germinate. If they dry again, they may lose viability or vigor.

Starting Seeds

Media

A wide range of materials can be used to start seeds, from straight vermiculite or mixtures of soilless artificial media to the various amended soil mixes. With experience, you will learn what works best under your conditions. Always keep the desirable qualities of a germinating medium in mind. The medium should be rather fine and uniform, yet well-aerated and loose. It should be free of insects, disease organisms and weed seeds. It should also be low in fertility, low in soluble salts, and capable of holding and moving moisture by capillary action. One medium with these qualities is a combination of one-third sterilized soil, one-third sand or vermiculite or perlite, and one-third peat moss.

The importance of using a sterile medium and container cannot be over emphasized. The home gardener can sterilize a small quantity of soil mixture in an oven. Place the slightly moist soil in a heat-resistant, covered container or pan in an oven heated to 250° F. Using a candy or meat thermometer, make sure the mix reaches a temperature of 180° F for at least one-half hour. This process typically produces very unpleasant odors. Avoid overheating as this can be extremely damaging to the soil. This treatment should prevent damping-off and other plant diseases as well as eliminate potential plant pests. Wood or plastic growing containers and implements should be washed to remove any debris, then rinsed in a 10 percent bleach/90 percent water solution. Avoid recontamination of the medium and tools.

To sterilize soil media in a microwave oven, place the moist soil in a shallow, covered dish. Heat for 10 to 15 minutes on high and allow to cool before using.

An artificial, soilless mix also can serve as a good germination medium. The basic ingredients include sphagnum peat moss and vermiculite, both of which are generally free of diseases, weed seeds, and insects. These ingredients also are readily available, easy to handle, and lightweight. They produce uniform plant growth.

Ready-made "peat-lite" mixes or similar products are available commercially. One homemade combination includes 4 quarts shredded sphagnum peat moss, 4 quarts fine grade vermiculite, 1 tablespoon superphosphate, and 2 tablespoons ground limestone. Another combination is 50 percent vermiculite or perlite and 50 percent milled sphagnum moss with fertilizer. Mix thoroughly. Since these mixes have little fertility, seedlings must be watered with a diluted fertilizer solution soon after they emerge. Do not use garden soil alone to start seedlings because it is too heavy and isn't sterile, doesn't drain well and will shrink from the sides of containers if allowed to dry.

Containers

Wooden or plastic flats and trays can be purchased or made from scrap lumber. A convenient size is about 12 to 18 inches long, 12 inches wide and about 2 inches deep. Leave cracks about 1/8 inch between the boards in the bottom or drill a series of holes for adequate drainage.

Clay or plastic flower pots also can be used. You can make your own containers for starting seeds by recycling cottage cheese containers or using the bottoms of milk cartons, bleach containers, or pie pans, as long as proper drainage is provided.

Numerous types of pots and strips made of compressed peat for starting seeds also are on the market, along with plant bands and plastic cell packs. Each cell or minipot holds a single plant, reducing the risk of root injury during transplanting. Peat pellets, peat- or fiber-based blocks, and expanded plastic foam cubes also can be used for seeding. With these, the growing medium itself forms the container unit.

Seeding

The proper time to sow seeds for transplants depends on when plants can be safely moved outside in your area (table 1). This period may range from 4 to 18 weeks prior to transplanting, depending on the germination speed, the growth rate, and cultural conditions. A common mistake is to sow the seeds too early and then attempt to hold the seedlings back under poor light or improper temperature ranges. This usually results in tall, weak and spindly plants that do not perform well in the garden.

Fill the moistened medium to 3/4 of an inch from the container's top. For very small seeds, at least the top 1/4 inch should be a fine, screened mix, or a layer of vermiculite. Firm the medium at the corners and edges with your fingers or a wood block to provide a uniform, flat surface.

For medium to large seeds, make furrows about 1 to 2 inches apart and 1/8 to 1/4 of an inch deep across the surface of the container, using a narrow board or pot label. Good light and air movement results from sowing in rows. Also, if damping-off fungus appears, there is less chance of it spreading. Seedlings in rows are easier to label and handle at transplanting time than those that have been sown by broadcasting. Sow the seeds thinly and uniformly in the rows by gently tapping the seed packet as it is moved along the row. Lightly cover the seeds with dry vermiculite or sifted medium if they require darkness for germination. A suitable planting depth usually is about twice the seed's diameter.

Do not plant seeds too deeply. Extremely fine seeds, such as petunia, begonia, or snapdragon, are not covered. Instead, they are lightly pressed into the medium or watered-in with a fine mist spray. If these seeds are broadcast, strive for a uniform stand by sowing half the seeds in one direction and the other half in the opposite direction.

Large seeds frequently are sown into a small container or cell pack, which eliminates the need for early transplanting. Usually two or three seeds are sown per unit and later thinned to allow the strongest seedling to grow.

Seed Tape

Most garden stores and seed catalogs offer indoor and outdoor seed tapes. Seed tape has precisely spaced

Table 1. Seed germination requirements.

Plant	Approximate Time To Seed Before Last Spring Frost	Approximate Germination Time (days)	Germination Temperature (0°/f)	Germination in Light (L) or Dark (D)
Begonia	12 weeks or more	10-15	70	L
Browallia		15-20	70	L
Geranium		10-20	70	L
Larkspur		5-10	55	D
Pansy (Viola)		5-10	65	D
Vinca		10-15	70	D
Dianthus	10 weeks	5-10	70	-
Impatients		15-20	70	L
Petunia		5-10	70	L
Portulaca		5-10	70	D
Snapdragon		5-10	65	L
Stock		10-15	70	-
Verbena		15-20	65	D
Ageratum	8 weeks	5-10	70	L
Alyssum		5-10	70	-
Broccoli		5-10	70	-
Cabbage		5-10	70	-
Cauliflower		5-10	70	-
Celosia		5-10	70	-
Coleus		5-10	65	L
Dahlia		5-10	70	-
Eggplant		5-10	70	-
Head lettuce		5-10	70	L
Nicotiana		10-15	70	L
Pepper		5-10	80	-
Phlox		5-10	65	D
Aster	6 weeks	5-10	70	-
Balsam		5-10	70	-
Centaurea		5-10	65	D
Marigold		5-10	70	-
Tomato		5-10	80	-
Zinnia		5-10	70	-
Cucumber	4 weeks or less	5-10	85	-
Cosmos		5-10	70	-
Muskmelon		5-10	85	-
Squash		5-10	85	-
Watermelon		5-10	85	-

seeds enclosed in an organic, water-soluble material. When planted, the tape dissolves, and the seeds germinate normally. Seed tapes are especially convenient for tiny, hard-to-handle seeds. However, tapes are much more expensive per seed. Seed tapes allow seedlings to emerge uniformly, eliminate overcrowding, and permit sowing in perfectly straight rows. The tapes can be cut at any point for multiple-row plantings, and thinning is rarely necessary.

Pregermination

Another method of starting seeds is pregermination. This involves sprouting the seeds before they are planted in pots or in the garden. It reduces the time to germinate as the temperature and moisture are easy to control, and it guarantees a high percentage of germination since none will be lost to environmental factors. Using a pan, lay seeds between the folds of a cotton cloth on a layer of vermiculite or similar material. Keep it moist and in a warm place. When roots begin to show, place the seeds in containers or plant them directly in the garden. When transplanting seedlings, be careful not to break off tender roots. Continued attention to watering is critical.

When planting seeds in a container that will later be set out in the garden, place one pregerminated seed in a 2- to 3-inch container. Plant the seeds to only half the recommended depth. Gently press a little soil over the sprouted seed and then add about 1/4 inch of milled sphagnum or sand to the soil surface. These materials will keep the surface uniformly moist and are easy for the shoot to push through. Keep the pots in a warm place and care for them just as any other newly transplanted seedlings.

A convenient way to plant small, delicate, pregerminated seeds is to suspend them in a gel. Make a gel by blending cornstarch and boiling water to a consistency that is thick enough for the seeds to stay suspended. Be sure to cool the gel thoroughly before use. Place the gel and seedlings in a plastic bag with a hole in it. Squeeze the gel through the hole along a premarked garden row. Spacing of seeds is determined by the number of seeds in the gel. If spacing is too dense, add more gel; if its too wide, add more seeds. The gel will keep the germinating seeds moist until they become established in the garden soil.

Watering

After the seed has been sown, thoroughly moisten the planting mix. Use a fine mist spray or place the containers in a pan or tray with an inch of warm water in the bottom. Avoid splashing or excessive flooding, which might displace small seeds. When the planting mix is saturated, set the container aside to drain. The soil should be moist but not wet.

Ideally, seed flats should remain sufficiently moist during the germination period without having to add water. Maintain moisture by slipping the entire flat or pot into a clear plastic bag after the initial watering. The plastic should be at least 1 to 1 1/2 inches from the soil. Keep the container out of direct sunlight or the high temperatures may harm the seeds. Many home gardeners cover their flats with panes of glass instead of plastic sleeves. Be sure to remove the plastic bag or glass cover as soon as the first seedlings appear. Surface watering then can be practiced, if care and good judgment are used.

Hand watering can lead to lack of uniformity, overwatering, and drying out. Excellent germination and moisture uniformity can be obtained with a low-pressure misting system. During spring days, 4 seconds of mist every 6 minutes. or 10 seconds every 15 minutes seem to be satisfactory. Bottom heat is an asset with a mist system. Subirrigation or watering from below may work well to keep the flats moist. However, since the flats or pots must sit in a constant water level, the soil may absorb too much water and the seeds may rot due to lack of oxygen.

Temperature and Light

Several factors that assure good germination already have been mentioned. The last item, but by no means the least important, is temperature. Since most seeds germinate best at an optimum temperature that is usually higher than most nighttime temperatures, special warm areas often are necessary. The use of thermostatically controlled heating cables is an excellent way to provide constant heat.

After germination and seedling establishment, move the flats to a light, airy and cool location. Temperatures should range from 55° to 60° F at night and 65° to 70° F during the day. This prevents soft, leggy growth and minimizes disease problems. Some crops, of course, may germinate or grow best at different temperatures and must be handled separately from the bulk of the plants.

Seedlings must receive bright light after germination. If possible, place them in a window facing south. If a large, bright window is not available, place the seedlings under a fluorescent light. Use two 40-watt, cool white fluorescent tubes or special plant growth lamps. Position the plants 6 inches from the tubes and keep the lights on them for about 16 hours each day. Raise the lights as the seedlings grow.

Transplanting and Handling Seedlings

If plants have not been seeded in individual containers, they must be transplanted for proper growing space. A common mistake is to leave the seedlings in the seed flat too long. Ideally, transplant young seedlings when they are small and there is little danger from setback. This usually occurs when the first true leaves appear above or between the cotyledon leaves (the cotyledons or seed leaves are the first leaves the seedling produces). Do not let plants get hard and stunted or too tall and leggy.

Seedling growing mixes and containers may be purchased or prepared by methods similar to those mentioned for germinating seed. However, the medium should contain more plant nutrients than a germination mix. Some commercial soilless mixes already have fertilizer added. When fertilizing, use a soluble, houseplant fertilizer at the dilution recommended by the manufacturer about every 2 weeks after the seedlings are established. Remember that young seedlings are easily damaged by too much fertilizer, especially if they are under any moisture stress.

To transplant, carefully dig the small plants up with a knife or wooden plant label. Let the group of seedlings fall apart and pick out individual plants. Gently ease them apart in small groups, this makes it easier to separate individual plants. Avoid tearing roots in the process. Handle small seedlings by the leaves, not the delicate stems. Punch a hole in the medium into which the seedling will be planted. Make the hole the same depth that the seedling was growing in the seed flat. Small plants or slow growers should be placed about 1 inch apart, while rapid-growing, large seedlings should be placed about 2 inches apart. After planting, firm the soil and water gently. Keep newly transplanted seedlings away from direct heat in the shade for a few days or place them under fluorescent lights. Continue watering and fertilizing as with the seed flats.

It is easy to transplant most plants that can be started indoors. A few plants are difficult to transplant. These usually are seeded directly outdoors or sown directly into individual containers indoors. Examples include zinnias and cucurbits, such as melons and squash.

Containers for Transplanting

A wide variety of containers are available for transplanting seedlings. Containers should be economical, durable, and space efficient. The type of container needed depends on the type of plant to be transplanted and the growing conditions. Standard pots may be used, but they waste a great deal of space and may not dry out rapidly enough for the seedling to have sufficient oxygen for proper development.

There are many types of containers available commercially. Pressed peat containers can be purchased in various sizes. Individual pots or strips of connected pots fit closely together are inexpensive and can be planted directly in the garden. When setting out plants grown in peat pots, be sure to cover the pot completely. If the peat pot's top edge extends above the soil level, it may act as a wick and draw water away from the soil in the pot. To avoid this, tear off the pot's top lip and plant it flush with the soil level.

Community packs have enough room to plant several plants. These inexpensive containers generally are made of pressed paper or fiber. The main disadvantage of a community pack is that the roots of the individual plants must be broken or cut apart when separating them to place in the garden.

When soaked in water, compressed peat pellets expand to form compact individual pots. They do not waste space or fall apart as readily as peat pots, and they can be set directly set in the garden. To avoid transplanting altogether, use compressed peat pellets for direct sowing of seedlings.

Community packs and cell packs, which are strips of connected individual pots, also are available in plastic. These are used frequently by commercial bedding plant growers, because they withstand frequent handling.

In addition, many homeowners use a variety of household materials for containers. Homemade containers should be deep enough to provide adequate soil and should have plenty of holes for drainage in the bottom.

Hardening Plants

Hardening is the process of altering the quality of plant growth to withstand changes in environmental conditions that occur when plants are transferred from a greenhouse or home to the garden. A severe check in plant growth may occur if plants produced in the home are planted outdoors without undergoing a transition period. Hardening is less critical for crops planted later in the season than for crops planted earlier, when adverse climatic conditions can be expected.

Hardening is accomplished by gradually lowering temperatures and relative humidity while reducing water. This results in an accumulation of carbohydrates and a thickening of cell walls. The change from a soft, succulent type of growth to a firmer, harder type of growth is desired.

Hardening should be started at least two weeks before planting in the garden. If possible, plants should be moved to an indoor area that is 45° to 50° F or outdoors to a shady location. A cold frame is excellent for this purpose. When put outdoors, plants should be shaded and then gradually moved into sunlight by increasing the length of exposure each day. Do not put tender seedlings outdoors on windy days or when temperatures are below 45° F. Even cold-hardy plants will be hurt if exposed to freezing temperatures before they are hardened. After proper hardening, however, they can be planted outdoors and light frosts will not damage them.

The hardening process is intended to slow plant growth. If carried to the extreme of actually stopping plant growth, significant damage can be done to certain crops. For example, cauliflower will make thumb size heads and fail to develop if hardened too severely. Cucumbers and melons also will stop growth if hardened incorrectly.

Propagation of Ferns by Spores

Although ferns can be easily propagated by other methods, some gardeners like the challenge of raising them from spores. One tested method for small quantities is described below.

Ingredients needed:

Mature fern spores
Distilled water
3-4 drops dishwashing detergent
Eye dropper
Jiffy peat pellets
Clear shallow dish
Clear disposable plastic cup

Begin by soaking jiffy pellets in water. After about an hour, they will at least double in size and will be ready to use. While the jiffy pellets are soaking, put 3-4 drops of dishwashing detergent in 1 cup of distilled water in a separate container. Place your fern frond over the soapy water solution. Now place the jiffy pellet on a clear shallow dish and gently pull away the netting from the top of the jiffy pellet. Using an eye dropper, extract liquid from the soapy water solution and gently squeeze it over the top of the jiffy pellet. The solution will contain many fern spores that will come into contact with the jiffy pellet. Cover the jiffy pellet with a clear disposable plastic cup.

It may take up to a month or more for the spores to germinate. Keep moist at all times. The sexual stage, called the prothallus, will develop initially from each spore, forming a light green mat. Mist lightly once a week to maintain high surface moisture; the sperm must be able to swim to the archegonia (female parts). Fertilization should occur after 3 weeks.

A green mat should form on the top of the jiffy pellet and soon the fern fronds will form. Gradually reduce the humidity, so that the ferns can survive in the open by either putting small holes in the plastic cup or lifting the cup slightly each day. After several weeks, pull apart the jiffy pot and transplant ferns to individual containers.

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