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University of Kentucky
College of Agriculture, Food and Environment
Cooperative Extension Service

Plant Propagation

Kentucky Master Gardener Manual Chapter 3

Adapted from the *Virginia Master Gardener Handbook.* Edited by Ray McNeilan, extension agent emeritus, Multnomah County, Oregon State University. Edited for Kentucky by Richard Durham, extension consumer horticulture specialist and master gardener state coordinator, University of Kentucky.

In this chapter:

Sexual Propagation

Sexual propagation involves the union of the pollen (male) with the egg (female) to produce a seed. The seed is made up of 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 is mature and put in a favorable environment, it will germinate, or begin active growth. In this section, seed germination and transplanting of seeds are discussed.

Seed

To obtain quality plants, start with good quality seed from a reliable dealer. Select varieties that will provide the size, color, and habit of growth desired. Choose varieties adapted to your area that will reach maturity before an early frost. Many new vegetable and flower varieties are hybrids, which cost a little more than open pollinated types. However, hybrid plants usually have more vigor and uniformity and better production than nonhybrids and sometimes have specific disease resistance or other unique cultural characteristics.

Although some seeds will keep for several years if stored properly, it is advisable to purchase only enough seed for the current year's use. Good seed will not contain seed of any other crop or debris. Printing on the seed packet usually indicates essential information about the variety, the year for which the seeds were packaged, germination percentage you may typically expect, and notes of any chemical seed treatment. If seeds are obtained well in advance of the actual sowing date or are stored surplus seeds, keep them in a cool, dry place. Laminated foil packets help ensure dry storage. Paper packets are best kept in tightly closed containers and maintained around 40° F in low humidity.

Some gardeners save seed from their own gardens; however, such seed is the result of random pollination by insects or other natural agents and may not produce plants typical of the parents, which is especially true of the many hybrid varieties. (See the vegetables chapter for information on saving vegetable seed.) Most seed companies take great care in handling seeds properly. Generally, do not expect more than 65% to 80% of the seeds to germinate. From those germinating, expect about 60% to 75% to produce satisfactory, vigorous, sturdy seedlings.

Germination

There are four environmental factors that affect germination: water, oxygen, light, and heat.

Water

The first step in the germination process is imbibition, or absorption of water. Even though seeds have great absorbent power due to the nature of the seed coat, the amount of available water in the germination medium affects the uptake of water. An adequate, continuous supply of water is important to ensure germination. Once germination has begun, a dry period will cause death of the embryo.

Light

Light is known to stimulate or to inhibit germination of some seed. The light reaction involved here is a complex process. Examples of crops that need light to assist seed germination are ageratum, begonia, browallia, impatiens, lettuce, and petunia. Conversely, calendula, centaurea, annual phlox, verbena, and vinca will 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 light-requiring seed, do as nature does, and leave them on the soil surface. If they are to be covered at all, cover them lightly with fine peat moss or fine vermiculite. These two materials, if not applied too heavily, will permit some light to reach the seed and will not limit germination. When starting seed in the home, supplemental light can be provided by fluorescent fixtures suspended 6 to 12 inches above the seeds for 16 hours a day.

Oxygen

In all viable seed, respiration takes place. Respiration in dormant seed is low, but some oxygen is required. The respiration rate increases during germination; therefore, the medium in which the seeds are 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

A favorable temperature is another important requirement of germination. It affects the rate of germination as well as germination percentage. Some seeds will germinate over a wide range of temperatures, while others require a narrow range. Many seed have minimum, maximum, and optimum temperatures at which they germinate. For example, tomato seed has a minimum germination temperature of 50° F and a maximum temperature of 95° F but an optimum germination temperature of about 80° F. When germination temperatures are listed, usually the optimum temperatures are given unless otherwise specified. Generally, 65° to 75° F is best for most plants. This range means germination flats often have 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 have been met. A seed must have a mature embryo, contain an endosperm large enough to sustain the embryo during germination, and contain sufficient hormones to initiate the process.

Methods of Breaking Dormancy

One of the functions of dormancy is to prevent a seed from germinating before it is surrounded by a favorable environment. In some trees and shrubs, seed dormancy is difficult to break, even when the environment is ideal. The seed can be treated in various ways to break dormancy and cause it to begin germinating.

Seed scarification

Seed scarification involves breaking, scratching, or softening the seed coat so that water can enter and begin the germination process. There are several methods of scarifying seeds. In acid scarification, seeds are put in a glass container and covered with concentrated sulfuric acid. The seeds are gently stirred and allowed to soak from 10 minutes to several hours, depending on the hardness of the seed coat. When the seed coat has become thin, 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. Hot water scarification involves putting the seed into water that is 170° to 212° F. The seeds are allowed to soak in the water as it cools for 12 to 24 hours and then planted. A fourth method is one of warm, moist scarification. In this case, seeds are stored in nonsterile, warm, damp containers, where the seed coat will be broken down by decay over several months.

Seed stratification

Seeds of some fallripening trees and shrubs of the temperate zone will not germinate unless chilled underground as they overwinter. This so-called "afterripening" can be accomplished artificially by a practice called "stratification."

The following stratification procedure is usually successful. Put sand or vermiculite in a clay pot to about 1 inch from the top. Place the seeds on top of the medium and cover with ½ 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 seal. Place the bag in a refrigerator. Periodically check to see that the medium is moist but not wet. Additional water will probably 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, and 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 pots to grow until time for setting outside.

Another procedure that is usually successful uses sphagnum moss or peat moss. Wet the moss thoroughly, then squeeze out excess water with your hands. Mix seed with the sphagnum or peat and place in a plastic bag. Seal the bag and put it in a refrigerator. Check it periodically. If there is condensation on the inside of the bag, the process will probably be successful. After 10 to 12 weeks, remove the bag from the refrigerator and plant the seeds in pots to germinate and grow. Handle seeds carefully, because often the small roots and shoots are emerging at the end of the stratification period and care must be taken not to break these off. Temperatures in the range of 35° to 45° F (2° to 7° C) are effective, and most refrigerators operate in this range. Seeds of most fruit and nut trees can be successfully germinated by these procedures. Seeds of peaches should be removed from the hard pit. Care must be taken when cracking pits, because any injury to the seed itself can be an entry path for disease organisms.

Starting Seeds

Media

A wide range of materials can be used to start seeds, from plain vermiculite or mixtures of soilless media to various amended soil mixes. With experience, you will learn what works best under your conditions. However, keep in mind that germinating medium should be rather fine and uniform, but also well aerated and loose. It also should be free of insects, disease organisms, and weed seeds; of low fertility (indicated by low total soluble salts); and capable of holding and moving moisture by capillary action.

The importance of using a sterile medium and container cannot be overemphasized (Figure 1). The home gardener can treat a small quantity of soil mixture in an oven to make it sterile. Place slightly moist soil in a heat-resistant container in an oven set at about 250° F. Use a candy or meat thermometer to ensure that the mix reaches a temperature of 140° F (or up to 180° F to control weed seeds) for at least 30 minutes. Avoid overheating, as it can be extremely damaging to the soil. Be aware that the heat will release unpleasant odors during the sterilization process. This treatment should prevent damping-off and other plant diseases as well as eliminate potential plant pests. Growing containers and implements should be washed to remove any debris then rinsed in a solution of 1 part chlorine bleach to 10 parts water.

An artificial, soilless mix can also provide a good germination medium and produce uniform plant growth. The basic ingredients of such a mix are sphagnum peat moss and vermiculite, both of which are readily available, easy to handle, and lightweight. One mixture that has these characteristics is a combination of ⅓ sterilized soil, ⅓ sand or vermiculite or perlite, and ⅓ sphagnum peat moss.

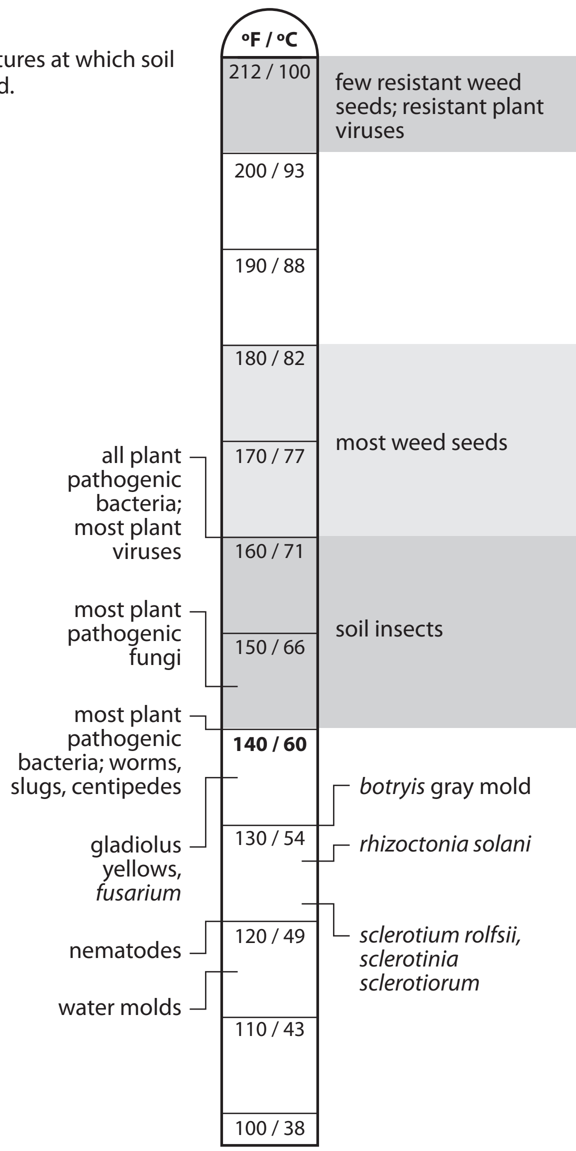


Figure 1. Temperatures at which soil organisms are killed.

"Peatlite" mixes or similar products are commercially available or can be made at home using this recipe: 4 quarts of shredded sphagnum peat moss, 4 quarts of fine vermiculite, 1 tablespoon of superphosphate, and 2 tablespoons of ground limestone. (Superphosphate and ground limestone are generally readily available from most garden centers or farm supply stores and can be found in the fertilizer section.) Mix thoroughly. These mixes have little fertility, so seedlings must be watered with a diluted fertilizer solution soon after they emerge. Do not use garden soil by itself to start seedlings; it is not sterile, is too heavy, and will not drain well.

Containers

Flats and trays can be purchased, or you can make your own from scrap lumber. A convenient size would be 12 to 18 inches long, 12 inches wide, and 2 inches deep. To ensure good drainage, leave an opening about ⅛ inch wide between boards in the bottom of the tray or drill a series of holes where two board meet.

You can also make your own containers for starting seeds by recycling cottage cheese containers, bottoms of milk cartons, bleach bottles, metal pie pans, etc. as long as good drainage is provided. At least one company has developed a form for recycling newspaper to make pots, and another has developed a method for the consumer to make and use compressed blocks of soil mix instead of pots. Clay or plastic pots also can be used.

Numerous types of pots and strips made of compressed peat are on the market. Plant bands and plastic cell packs, which are strips of connected individual pots, are also available. With these types of containers, each cell or minipot holds a single plant, which reduces the risk of root injury when transplanting. Peat pellets, peat or fiber-based blocks, and expanded foam cubes can also be used for seeding.

Seeding

The proper time for sowing seeds for transplants depends upon when plants may safely be moved outdoors in your area. This period can be from 4 to 12 weeks prior to transplanting, depending upon speed of germination, rate of growth, and cultural conditions such as temperature and amount of sunlight (Table 1). A common mistake is to sow seeds too early and then attempt to hold the seedlings back under poor light or improper temperature ranges, which usually results in tall, weak, spindly plants that do not perform well in the garden.

Steps for seeding (see Figure 2):

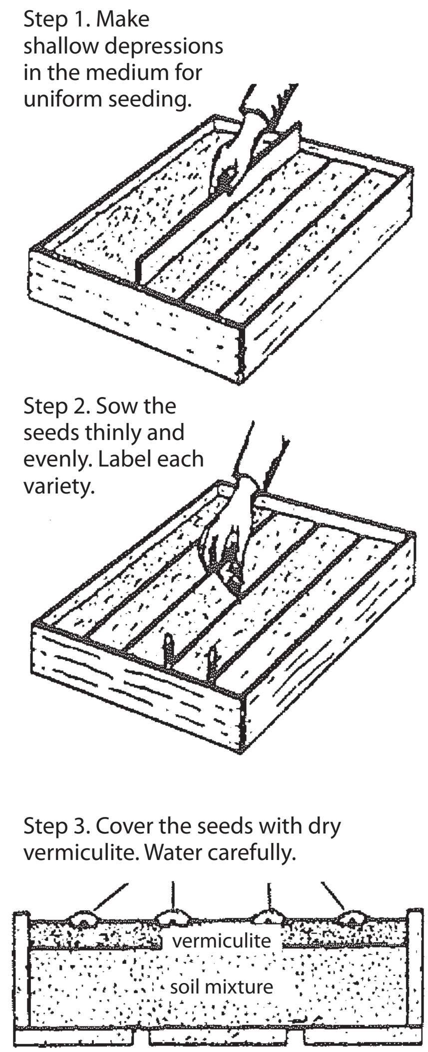
After selecting a container, fill it with moistened growing medium to within ¾ inch of the top. For very small seeds, at least the top ¼ inch should be a fine, screened mix or a layer of vermiculite. Firm the medium at the corners and edges with your fingers or a block of wood to provide a uniform, flat surface.

For medium and large seeds, make furrows 1 to 2 inches apart and ⅛ to ¼ inch deep across the surface of the container using a narrow board, pointed end of a plastic pot label, or even the dull point of a pencil. Sowing in rows produces good exposure to light and air movement, and if damping-off fungus appears, there is less chance of it spreading. Also, seedlings in rows are easier to label and handle at transplanting time than those that have been sown in a broadcast manner. Sow seeds thinly and uniformly in rows by gently tapping the packet of seed as you move it along the row. If seed require darkness for germination, lightly cover them with dry vermiculite or sifted medium.

Do not plant seeds too deeply. A suitable planting depth is usually about twice the diameter of the seed. Extremely fine seed such as petunia, begonia, and snapdragon are not covered; they are lightly pressed into the medium or watered in with a fine mist. If fine seeds are broadcast, strive for a uniform stand by sowing half the seeds in one direction, then sowing the remaining seed in the opposite crosswise direction.

Large seeds are frequently sown into some sort of small container or cell pack, eliminating the need for early transplanting. To allow the strongest seedling to grow, two or three large seeds usually are sown per unit and later thinned.

Figure 2. Sowing seeds in a starter flat.



Seed tape

Most garden stores and seed catalogs offer indoor and outdoor seed in tape. Seed tape, although much more expensive per seed, has precisely spaced seeds enclosed in an organic, water-soluble material. When planted, the tape dissolves and seeds germinate normally. Seed tapes are especially convenient for tiny, hard-to-handle seeds. They allow uniform emergence, eliminate overcrowding, and permit sowing in perfectly straight rows. Tapes can be cut at any point for multiple-row plantings, and thinning is rarely necessary.

Table 1. Seed Requirements.

Approx. Time to Seed before Last Spring Frost*	Plant	Approx. Germ. Time (days)	Germ. Temp. (Degrees F)	Germ. in Light (L) or Dark (D)
12 weeks or more	Begonia	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
10 weeks	Dianthus	5 - 10	70	--
	Impatiens	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
8 weeks	Ageratum	5 - 10	70	L
	Allyssum	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
6 weeks	Aster	5 - 10	70	--
	Balsam	5 - 10	70	--
	Centurea	5 - 10	65	D
	Marigold	5 - 10	70	--
	Tomato	5 - 10	80	--
	Zinnia	5 - 10	70	--
4 weeks or less	Cucumber	5 - 10	85	--
	Cosmos	5 - 10	70	--
	Muskmelon	5 - 10	85	--
	Squash	5 - 10	85	--
	Watermelon	5 - 10	85	--

*Length of time is based on relative rate of seeding growth and how long it will take to obtain a sizeable transplant.

Pregermination

Another method of starting seeds is pregermination, which involves sprouting seeds before they are planted in pots or in the garden. This method reduces time to germination, as temperature and moisture are easy to control. A high percentage of germination is achieved, since environmental factors are optimum. To pregerminate seeds, lay them between folds of a cotton cloth or on a layer of vermiculite in a shallow pan. Keep seed in a warm place, and, because continued attention to watering is critical, keep the cloth or vermiculite moist. When roots begin to show, place seeds in containers or plant them directly in the garden. While transplanting pregerminated seedlings, be careful not to break off tender roots.

When planting pregerminated seeds in containers that will be set out in the garden later, use containers that are 2-3 inches in diameter, with one seed per container. Plant the seeds at only half the recommended depth. Gently press a little soil over the sprouted seed and then add about ¼ inch of milled sphagnum or sand to the soil surface, which will keep the surface uniformly moist and enable the shoot to push through easily. Keep these containers in a warm place and care for the seedlings as for any other newly transplanted seedlings.

Watering

After the seed has been sown, thoroughly moisten the planting mix. Use a fine mist or place the containers in a pan or tray that contains about 1 inch of warm water. 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. One way to maintain moisture is to slip the whole flat or pot into a clear plastic bag after the initial watering. The plastic should be at least 1 inch from the soil. Keep the container out of direct sunlight; otherwise, the temperature may rise to the point at which the seeds will be harmed. Many home gardeners cover their flats with panes of glass instead of a plastic sleeve. Be sure to remove the plastic bag or glass cover as soon as the first seedlings appear. You can then surface-water if you do it carefully and use good judgment.

Manual watering, if not done uniformly, can result in plants being overwatered or drying out. Excellent germination and moisture uniformity can be obtained with a low-pressure misting system. In the spring, a satisfactory schedule might be, during the daytime, 4 seconds of mist every 6 minutes or 10 seconds of mist every 15 minutes. Misting should be monitored from time to time and the frequency adjusted to ensure that the medium is not waterlogged.

Bottom heat is an asset with a mist system. As mist and water in the medium evaporates, the medium is cooled. Bottom heat will provide more uniform temperatures to aid germination. Sub-irrigation or watering from below can work well to keep the flats moist, but because the flats or pots are sitting in water constantly, the soil may absorb too much water, and the seeds may rot due to lack of oxygen.

Temperature and light

Since most seeds will germinate best at an optimum temperature that is usually higher than most home night temperatures, special warm areas often must be provided. The use of thermostatically controlled heating cables is an excellent method of providing constant heat.

After germination and seedling establishment, move flats to a light, airy, cooler location at a 55° to 60° F night temperature and a 65° to 70° F day reading, which will prevent soft, leggy growth and minimize disease troubles. Some crops, of course, may germinate or grow best at a different constant temperature and must be handled separately from the bulk of the plants.

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

Transplanting and Handling

If plants have not been seeded in individual containers, they must be transplanted to give them proper growing space. One of the most common mistakes made is leaving the seedlings in the seed flat too long. The ideal time to transplant young seedlings is when they are small and there is little danger from setback. This is usually about the time the first true leaves appear above or between the cotyledon leaves (the cotyledons or seed leaves are the first leaves the seedling produces). Don't let plants get hard and stunted or tall and leggy.

Seedling growing mixes and containers can be purchased or prepared similarly to those mentioned for germinating seed. The medium should contain more plant nutrients than a germination mix, however. Some commercial soilless mixes have fertilizer already added. When fertilizing, use a soluble house plant fertilizer at the dilution recommended by the manufacturer about every two weeks after 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 up the small plants 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, which will make it easier to separate individual plants. Avoid tearing roots, and handle small seedlings by their leaves, not their delicate stems. Punch a hole in the medium into which the seedling will be planted. Make it deep enough so the seedling can be put at the same depth at which it was growing in the seed flat. Small plants or slow growers should be placed 1 inch apart, and rapidly growing, large seedlings about 2 inches apart. After planting, firm the soil and water gently. Keep newly transplanted seedlings in the shade for a few days, or place them under fluorescent lights. Keep them away from direct heat sources, and continue watering and fertilizing as in the seed flats.

Most plants transplant well and can be started indoors, but a few plants are difficult to transplant. These are generally directly seeded outdoors or sown directly into individual containers indoors. Examples include zinnias and cucurbits such as melons and squash.

Propagation of Ferns by Spores

Though ferns are more easily propagated by other methods, some gardeners like the challenge of raising ferns from spores. One tested method for small quantities follows:

Put a solid, sterilized brick (bake at 250° F for 30 minutes) in a pan and add water to cover the brick. When the brick is wet throughout, squeeze a thin layer of moist soil and peat (1:1) onto the top of the brick.

Pack a second layer (about an inch) on top of that. Sprinkle spores on top. Cover with plastic (not touching the spores) and put the plastic-encased brick in a warm place in indirect light. It may take up to a month or more for the spores to germinate. Keep the brick moist at all times.

A prothallus (one generation of the fern) will develop first from each spore, forming a light green mat. Mist the mat lightly once a week to maintain high surface moisture; the sperm must be able to swim to the archegonia (female parts). After about three weeks, fertilization should have occurred.

Pull the mat apart with tweezers in ¼-inch squares and space the squares ½ inch apart in a flat layering 2 inches of sand, ¼ inch of charcoal, and about 2 inches of soil/peat mix. Cover with plastic and keep moist.

When fern fronds appear and become crowded, transplant them to small pots. Gradually reduce humidity until the fern plants can survive in the open. Exposure to light may be increased at this time.

Containers for transplanting

A wide variety of containers for transplanting seedlings is available. Containers should be economical, durable, and make good use of space. The type selected will depend on the type of plant to be transplanted and individual 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.

Containers made out of pressed peat can be purchased in varying 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 top edge of the peat pot extends above the soil level, it may act as a wick and draw water away from the soil in the pot. To prevent this, tear off the top lip of the pot and then plant flush with the soil level.

Compressed peat pellets, when soaked in water, expand to form compact, individual pots. They waste no space, don't fall apart as badly as peat pots, and can be set directly out in the garden. If you wish to avoid transplanting seedlings altogether, compressed peat pellets are excellent for direct sowing.

Community packs are containers in which there is room to plant several plants. They are generally inexpensive. The main disadvantage of a community pack is that roots of individual plants must be broken or cut apart when separating the plants to put out in the garden.

Both community packs and cell packs are frequently used by commercial bedding plant growers, as they withstand frequent handling. In addition, many homeowners find a variety of materials from around the house useful for containers. These homemade containers should be deep enough to provide adequate soil and have plenty of drainage holes in the bottom.

Hardening plants

Hardening is the process of altering the quality of plant growth to withstand the change in environmental conditions that occurs when plants are transferred from a greenhouse or home to the garden. A severe check in growth may occur if plants produced in the home are planted outdoors without a transition period. Hardening is most critical with early crops, when adverse climatic conditions can be expected.

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

This process should be started at least two weeks before planting in the garden. If possible, plants should be moved to a 45° to 50° F temperature indoors or outdoors in a shady location. A cold frame is excellent for this purpose. When put outdoors, plants should be shaded, then gradually moved into sunlight. Each day, gradually increase the length of exposure. Reduce the frequency of watering to slow growth, but don't allow plants to wilt. Don't 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, plants 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 further if hardened too severely. Cucumbers and melons will stop growth if hardened.

Asexual Propagation

Asexual propagation is the best way to maintain some species, particularly an individual plant that best represents that species. Clones are groups of plants that are identical to their one parent and can only be propagated asexually. The Bartlett pear (first selected in 1770) and Delicious apple (first selected in 1870) are two examples of clones that have been asexually propagated for many years.

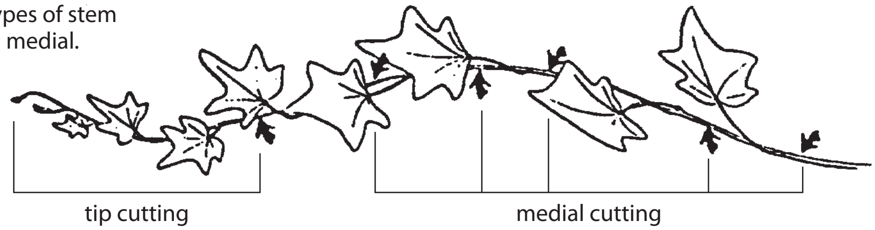
Major methods of asexual propagation are cuttings, layering, division, and budding/grafting. Cuttings involve rooting a severed piece of the parent plant; layering involves rooting a part of the parent and then severing it; and budding/grafting is joining two plant parts from different varieties.

Cuttings

Many types of plants, both woody and herbaceous, are frequently propagated by cuttings. 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 blade to reduce injury to the parent plant. First, dip the cutting tool in rubbing alcohol or a mixture of one part bleach to nine parts water to prevent transmitting diseases from infected plant parts to healthy ones. When making cuttings, start with the youngest tissues and move toward older tissue. Re-dip (disinfect) the cutting tool each time you move to a new branch or a new plant. 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 fruit and seed production. To hasten rooting, increase the number of roots, or to obtain uniform rooting (except on soft, fleshy stems), use a rooting hormone, preferably one containing a fungicide. Prevent possible contamination of the entire supply of rooting hormone by putting some in a separate container for dipping cuttings.

Figure 3. Two types of stem cuttings: tip and medial.



Insert cuttings into a rooting medium such as coarse sand, vermiculite, soil, water, or a mixture of peat and perlite. It is important to choose the correct rooting medium to get optimum rooting in the shortest time. In general, the rooting medium should be sterile, low in fertility, 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, indirect light. Root cuttings can be kept in the dark until new shoots appear.

Stem cuttings

Numerous plant species are propagated by stem cuttings. Some can be taken at any time of the year, but 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 (Figure 3). Make the cut just below a node. Remove lower leaves that would touch the medium or be below it. 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.

Medial cuttings

Make the first cut just above a node and the second cut just above a node 2-6 inches down the stem (Figure 3). Prepare and insert the cutting as you would a tip cutting. Be sure to position the cutting right side up. Axial buds are always above leaves.

Cane cuttings

Cut cane-like stems into sections containing one or two eyes, or nodes (Figure 4). Dust ends with fungicide or activated charcoal. Allow to dry several hours. Lay horizontally with about half of the cutting below the media surface, eye facing upward. Cane cuttings are usually potted when roots and new shoots appear, but new shoots from dracaena and croton are often cut off and re-rooted in sand.

Single-eye

The eye refers to the node. This is used for plants with alternate leaves when space or stock materials are limited. Cut the stem about ½-inch above and ½-inch below a node. Place cutting horizontally or vertically in the medium.

Figure 4. Other types of stem cuttings.

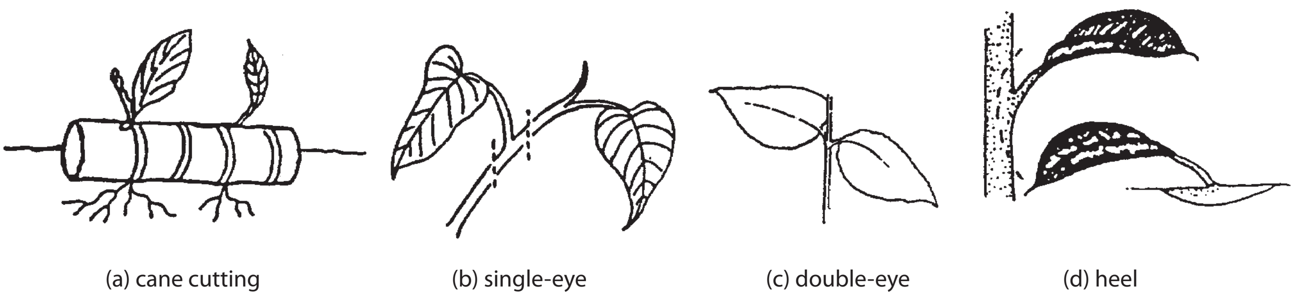


Figure 5. Types of leaf cuttings.

Double-eye

This is used for plants with opposite leaves when space or stock material is limited. Cut the stem about ½-inch above and ½-inch below the same node. Insert the cutting vertically in the medium with the node just touching the surface.

Heel cuttings

This method efficiently uses 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 just decay (Figure 5).

Whole leaf with petiole

Detach the leaf and up to 1½ inches of petiole. Insert the lower end of the petiole into the medium. One or more new plants will form at the base of the petiole. The leaf may be severed from new plants when they have their own roots and the petiole reused.

Whole leaf without petiole

This type of cutting is used for plants with sessile 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 margins with 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 arise 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 upper cut. 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 are usually taken from 2- to 3-year-old plants during their dormant season, when they have a large carbohydrate supply. Root cuttings of some species produce new shoots, which then form their own root systems, while root cuttings of other plants develop root systems before producing new shoots.

The method of taking root cuttings depends on the root size, as follows:

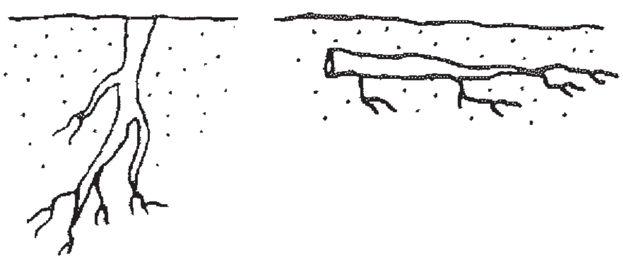
Plants with large roots

Make a straight top cut. Make a slanted cut 2 to 6 inches below the first cut. Store about three 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 surface of the rooting medium. This method is often used outdoors (Figure 6).

Plants with small roots

Take 1- to 2-inch sections of roots. Insert the cuttings horizontally about 12 inches below the medium surface (Figure 6). This method is usually used indoors or in a hotbed.

Figure 6. Root cuttings.



(a) plants with large roots (b) plants with small roots

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 method of vegetative propagation, called layering, promotes a high success rate because it prevents the water stress and carbohydrate shortage that plague cuttings.

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

Tip

Dig a hole 3 to 4 inches deep. Insert the shoot tip and cover it with soil. The tip grows down first, then bends sharply and grows upward. Roots form at the bend, and the re-curved tip becomes a new plant. Remove the tip layer and plant it in the early spring or late fall. *Examples:* purple and black raspberries, trailing blackberries.

Simple

Bend the stem to the ground. Cover part of it with soil, leaving the top 6 to 12 inches exposed. Bend the tip into a vertical position and stake in place. The sharp bend will often induce rooting, but wounding the lower side of the branch or loosening the bark by twisting the stem may help. *Examples:* rhododendron, honeysuckle.

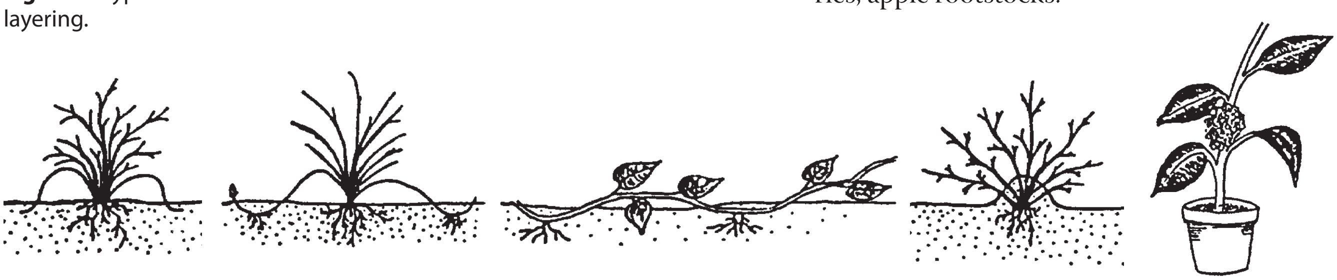
Compound

This method works for plants with flexible stems. Bend the stem to the rooting medium as for simple layering, but alternately cover and expose stem section, wounding the lower side of the stem sections to be covered. *Examples:* heart-leaf philodendron, pothos.

Mound (stool)

Cut the plant back to 1 inch above the ground in the dormant season. Mound soil over the emerging shoots in the spring to enhance their rooting. *Examples:* gooseberries, apple rootstocks.

Figure 7. Types of layering.



(a) tip layering (b) simple layering (c) compound layering (d) mound layering (e) air layering

Air

Air layering is used to propagate some indoor plants with thick stems or to rejuvenate them when they become leggy. 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 in place. When roots pervade the moss, cut the plant off below the root ball. *Examples:* dumbcane, rubber tree.

The following propagation methods can all be considered types of layering, as 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, then produce new shoots where it touches the medium. 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 new plants from their parent stems. Plantlets at the tips of runners may be rooted while still attached to the parent or detached and placed in a rooting medium. *Examples:* strawberry, spider plant.

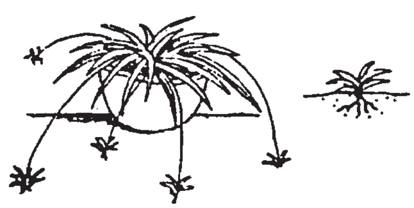


Figure 8. Propagation using stolons.

Offsets

Plants with a rosetted stem often reproduce by forming new shoots at their base or in leaf axils (Figure 9). Sever 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 offsets must be cut off, while others may be simply lifted off the parent stem. *Examples:* date palm, haworthia, bromeliads, many cacti.

Figure 9. A plant with offsets.

Separation

Separation is a term applied to a form of propagation by which plants that produce bulbs or corms multiply.

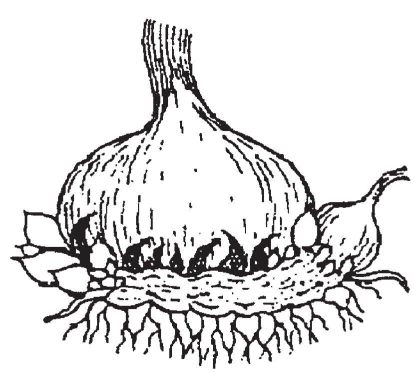
Bulbs

New bulbs form beside the originally planted bulb. Separate these bulb clumps every three to five years for largest blooms and to increase bulb population. 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 two or three years, but large ones should bloom the first year. *Examples:* tulip, narcissus.

Corms

A large new corm forms on top of the old corm, and tiny cormels form around the large corm (Figure 10). After the leaves wither, dig up the corms and allow them to dry in indirect light for two or three 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, when both the new corms and the cormels can be planted. The new corms are planted just like the previous corm and usually produce plants with bloom the first year. Cormels may take more than one year to produce blooms and should be planted at a more shallow depth (about 2 inches) during the first year and then planted as normal in succeeding years. *Examples:* crocus, gladiolus.

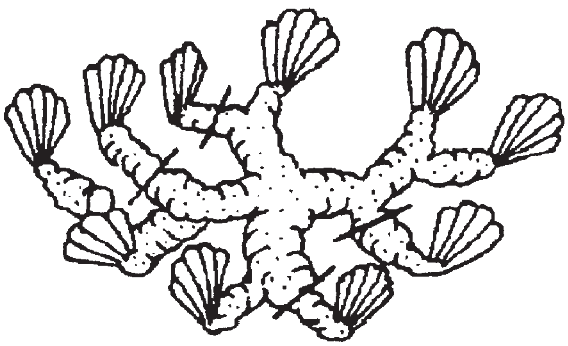
Figure 10. Separating corms.



Division

Plants with more than one rooted crown may be divided and the crowns planted separately. 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 (Figure 11). Divisions of some outdoor plants should be dusted with a fungicide before they are replanted. *Examples:* snake plant, iris, prayer plant, day lilies.

Figure 11. Division.



Grafting

Grafting and budding are methods of asexual plant propagation that join plant parts so they will grow as one plant. 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 portion of the cultivar that is to be propagated is called the "scion." It consists of a piece of shoot with dormant buds that will 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 wood and bark of a stem from which new bark and wood cells originate. (See Chapter 20, *Growing Tree Fruits,* for discussion of apple rootstock).

Four conditions must be met for grafting to be successful: 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 (Figure 12) is often used to change the cultivar or top growth of a shoot or a young tree (usually a seedling). It is especially successful if done in the early spring.

Collect scion wood ⅜ to ⅝ inch in diameter. Cut the limb or small tree trunk to be reworked perpendicular to its length. Make a 2-inch vertical cut through the center of the previous cut. Be careful not to tear the bark. Keep this cut wedged apart. Cut the lower end of each scion piece into a tapered point similar in size to the wedge used to hold the cut in the limb apart. Prepare two scion pieces 3 to 4 inches long. Insert 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 cambial layers of the scion and stock touch. Remove the wedge propping the slit open, and cover all cut surfaces with grafting wax.

Figure 12. Cleft grafting.

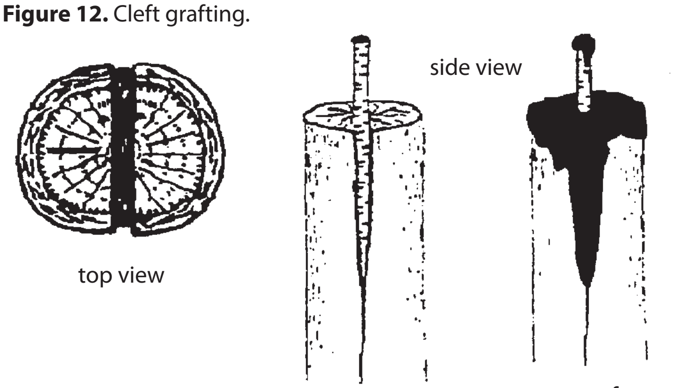


Figure 13. Bark graft.

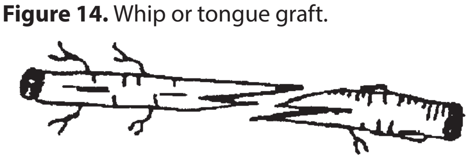
Bark grafting

Unlike most grafting methods, bark grafting (Figure 13) can be used on large limbs, although these limbs often become infected before the wound can heal completely. Collect scion wood ⅜ to ½ inch in diameter when the plant is dormant. Store the wood wrapped in moist paper in a plastic bag in the refrigerator. Saw off the limb or trunk of the rootstock at a right angle to itself. In the spring, when the bark is easy to separate from the wood, make a ½-inch diagonal cut on one side of the scion and a 1 ½-inch diagonal cut on the other side. Leave two buds above the longer cut. Make two parallel upright cuts through the bark of the stock so that the width of the cuts is a little wider then the width of the scion. Remove the top third of the bark from this cut. Insert the scion with the longer cut against the wood. Nail the graft in place with flat-headed wire nails. Cover all wounds with grafting wax.

Whip or tongue grafting

Whip or tongue grafting (Figure 14) is often used for material ¼ to ½ inch in diameter. The scion and rootstock are usually of the same diameter, but the scion may be narrower than the stock. This strong graft heals quickly and provides excellent cambial contact. Make one 2 ½-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 up into the scion so the pieces will interlock. Fit the pieces together, then tie and wax the union.

Figure 14. Whip or tongue graft.



Care of the graft

Very little success in grafting will be obtained without proper care for the following year or two. If a binding material such as strong cord or nursery tape is used on the graft, this tape must be cut shortly after growth starts to prevent girdling or constricting. Rubber budding strips have some advantages over other materials. They expand with growth and usually do not need to be cut because they deteriorate and break after a short time. It is also an excellent idea to inspect grafts after two or three weeks to see if the wax has cracked. If necessary, rewax exposed areas. The union will probably be strong enough after this waxing, and no more waxing will be necessary.

Limbs of the old variety that are not selected for grafting should be cut back at the time of grafting. The total leaf surface of the old variety should be gradually reduced until the new variety has taken over, which will take one or two years. Completely removing all limbs of the old variety at the time of grafting increases the shock to the tree and causes excessive suckering and may also cause scions to 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. It is especially useful when scion material is limited. It is also faster and forms a stronger union than grafting.

Patch budding

Plants with thick bark should be patch budded, which is done while plants are actively growing, so that 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 (Figure 15). 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 bark is not slipping. Slice downward into the rootstock at a 45° angle through ¼ of the wood. Make a second cut upward from the first cut, about 1 inch. Remove a bud and attending chip of bark and wood from the scion that is shaped so it fits the rootstock wound. Fit the bud chip to the stock and wrap the union (Figure 16).

T-budding

This is the most commonly used budding technique. When bark is slipping, make a vertical cut (same axis as the rootstock) through the bark of the rootstock, 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, bark, and a thin section of wood. Push the shield under the loosened stock bark. Wrap the union, leaving the bud exposed (Figure 17).

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. A new shoot will develop from the inserted bud, and other shoots may develop along the stem of the stock. Remove all buds from the stock except the one that arises from the inserted bud (scion). As the new shoot grows, it may be tied to the existing stub of the stock to prevent wind damage. 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.

Figure 15. Patch budding.

Figure 16. Chip budding.

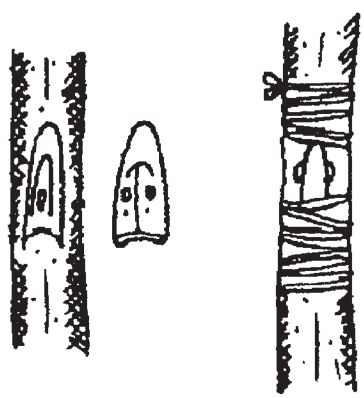


Figure 17. T-budding.