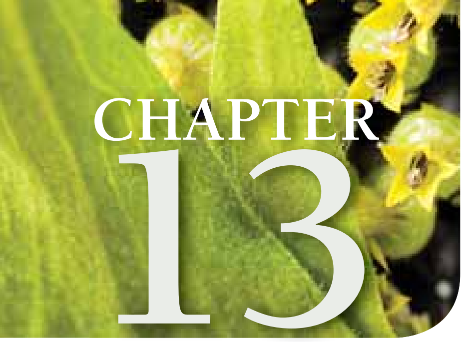


CHAPTER 13 Seed Propagation

Chapter Outcomes

After studying this chapter, you will be able to:

- Describe seed morphology and development.
- Understand the environmental conditions needed for optimal seed germination.
- Compare strategies to break dormancy responses in different seeds.
- Explain different seed propagation techniques.
- Summarize categories used for selecting seeds.
- Discuss production of high-quality seeds and seed saving and storage.
- Identify careers related to seed propagation operations and maintenance.

Words to Know

abscisic acid
apomixis
cell expansion
desiccation
genetically modified organism (GMO)
germplasm
histodifferentiation
imbibition
lag phase
landrace
maturation drying
phenol
photodormancy
plug
plumule
priming
quiescent
radicle
radicle protrusion
scarification
seedbed
seedlot
thermodormancy
transgenic
viable
vivipary

Before You Read

Read the chapter title and tell a classmate what you have experienced or already know about the topic. Write a paragraph describing what you would like to learn about the topic. After reading the chapter, share two things you have learned with the classmate.





While studying this chapter, look for the activity icon to:

- **Practice** vocabulary terms with e-flash cards and matching activities.
- **Expand** learning with the Corner Questions and interactive activities.
- **Reinforce** what you learn by completing the end-of-chapter questions.

www.g-wlearning.com/agriculture

rsooll/Shutterstock.com; shihina/Shutterstock.com; Smit/Shutterstock.com ; wasanajai/Shutterstock.com; Kathy Clark/Shutterstock.com

The magic of gardening begins with sowing a simple seed and watching it burst from the soil, sprouting into something wonderful. Horticulture is the pursuit of growing plants and it all starts with seeds. Consider the zinnia, an ornamental annual. Zinnias are a much-loved garden flower and a prolific bloomer. They produce many seeds that can be saved and planted next year, **Figure 13-1**.

Where do you start when trying to grow a seed? What do seeds need in order to grow? What if your seed does not grow? Seed propagation is the science and art of understanding a seed's biology and being able to coax it to germinate and flourish.

P.Tummavijit/Shutterstock.com

Figure 13-1. Zinnias can be sown directly in the garden and seeds from the flowers can be saved for the following year.

Seed Morphology and Development

A seed is the mature reproductive unit of gymnosperms and angiosperms. Seeds are formed as a result of the fertilization process. In addition to the formation of a seed, fertilization is also responsible for the genetic variation of a species. All seeds have an embryo, a protective outer covering, and storage tissue.

The protective covering of a seed may be its seed coat or the fruit (pericarp) that surrounds the seed. The storage tissue in dicots is contained in the cotyledons. For monocots, energy is stored as starchy tissue known as the endosperm. The storage tissue provides the initial energy needed to drive germination. Seeds and fruits come in a wide array of shapes, sizes, and appearances.

Stages of Seed Development

The three stages of seed development are histodifferentiation, cell expansion, and maturation drying.

Histodifferentiation

Histodifferentiation is a stage of seed development when the embryo and endosperm develop distinct characteristics. Seed size increases rapidly due to the process of cellular division. In dicots, this is the stage where cotyledons are formed. In monocots, more specialized structures are formed to aid in germination.

Cell Expansion

During ***cell expansion***, seeds undergo a phase of swift cell enlargement due to the accumulation of food reserves in the form of carbohydrates, fats, oils, and proteins.

Corner Question

What two plant families are responsible for almost all the food and feed crops that comprise the world's diet?

Maturation Drying

Maturation drying is the last stage of seed development. It is the point at which seeds have reached physiological maturity. Seeds experience rapid water loss through the vascular separation from the mother plant. The ***desiccation***, or drying of seeds, is a preparation for seeds to be ***quiescent*** or dormant. Quiescent seeds are in a state of inactivity, but will readily germinate if given water. Dormant seeds will fail to germinate under even favorable conditions, and require some sort of treatment to grow. ***Vivipary*** is a unique, natural phenomenon in which seeds germinate inside their fruit without maturation drying. Have you ever seen a seed within the fleshy fruit of a tomato begin to germinate, **Figure 13-2**? This is vivipary. In most plants this is an undesired genetic mutation. In others, such as the mangrove, vivipary allows a plant to compete for survival.

Kathy Clark/Shutterstock.com

Figure 13-2. This tomato is displaying vivipary, a condition in which seeds germinate before they are fully mature.

Radicle protrusion

Apomixis

Some plants are able to spontaneously produce seeds without going through the fertilization process. The process, called ***apomixis***, occurs asexually and creates genetic clones of the parent. Apomixis might happen when an embryo develops from an unfertilized egg nucleus that has not undergone meiosis. Many plants from the genus *Citrus* form embryos adventitiously. They can sometimes produce as many as six seedlings from a single embryo. It is nearly impossible to distinguish a clonally produced seedling from one that results from sexual fertilization.

"With every deed you are sowing a seed, though the harvest you may not see."
—Ella Wheeler Wilcox

Seed Germination

Germination is the process by which seeds begin to grow. Three conditions must be met in order for germination to occur:

- The seed must be ***viable*** (the embryo must be alive).
- Environmental conditions must be favorable. Water, proper temperature, oxygen, and sometimes light must be present.
- Dormancy conditions must be overcome.

If these conditions have been fulfilled, then the early phases of germination can begin. In early germination, three phases describe the process of a seed beginning to increase its water uptake:

- ***Imbibition*** is a physical process where water is rapidly taken up by the seed, hydrating the inner tissues.
- The ***lag phase*** is a period with little or no water uptake, but with many cellular activities that prepare the seed to grow.
- ***Radicle protrusion*** is the last period of early germination characterized by the emergence of the seed root, or ***radicle***, **Figure 13-3**.

Bogdan Wankowicz/Shutterstock.com

Figure 13-3. The seed root, or radicle, emerges during the last step of early germination.

The new seedling experiences root and shoot elongation. The growing point for the root is the radicle and the growing point for the developing shoot is the ***plumule***. As the seed embryo begins to grow, it draws upon its reserves of carbohydrates (starch), proteins, and lipids (oils) until photosynthesis starts to occur.

"The love of gardening is a seed once sown that never dies."
—Gertrude Jekyll

Germination Rates

Many seeds have variable germination rates and can be measured by three indicators: percentage, rate, and uniformity. A ***seedlot*** is made up of seeds of a particular crop gathered at one time, with similar germination rates and other characteristics. The number of seeds that germinate in a given seedlot defines the germination percentage. For example, if there are 100 seeds and 70 germinated, the germination percentage would be 70%. The germination rate measures the speed at which seeds will grow. Germination uniformity identifies the time frame in which the seeds emerge. In some seed species, these parameters are highly variable and also differ from season to season. Many plant breeders have breeding objectives that include better percentage, rate, and germination uniformity.

Environmental Conditions for Germination

Certain conditions must be present for seeds to germinate. Temperature, water, oxygen, and sometimes light can affect seed germination.

Temperature

Temperature is the most critical factor that regulates the timing of germination. Temperature influences seed dormancy control, germination percentage, and rate. Seed germination temperatures have been identified for most horticultural species and include a minimum, maximum, and optimum range. Minimum temperature is the lowest temperature at which germination will occur; maximum, the highest. Optimal temperature is where the largest percentage of seeds germinates at the fastest rate. Most seeds can be broadly grouped based on their temperature requirements.

STEM Connection

Love in a Puff

Love in a Puff (*Cardiospermum halicacabum*) is a delicate vine that trails up trellises using tendrils. After the vine bursts with dainty white flowers, they slowly form into an interesting fruit. Inflated with air like a beach ball, the "puff" is unique. Inside the puff is the fruit, little black seeds that have a white heart on them.

wasanajai/Shutterstock.com

Cool Temperature

Seeds in the cool temperature group prefer cooler soil temperatures for germination to occur. They can be further subdivided into *cool temperature tolerant* and *cool temperature requiring*. Cool temperature tolerant seeds germinate from 86°F (30°C) to about 104°F (40°C), with an optimum temperature of 77°F–86°F (24°C–30°C). Crops in this class include broccoli, cabbage, alyssum, and carrots. Cool temperature requiring crops will not germinate at temperatures higher than 77°F (25°C) and include many winter annuals such as celery, lettuce, onion, and primrose, **Figure 13-4**.

rhfletcher/Shutterstock.com

Figure 13-4. Primrose requires cool temperatures and will not germinate at temperatures above 77°F (25°C).

Warm Temperature

Plants in this category will not germinate at temperatures below 50°F (10°C) (asparagus, sweet corn, and tomato) or 60°F (15°C) (beans, eggplant, peppers, and cucumbers). Many of these plants will show symptoms of chilling injury if exposed to low temperatures.

Water

Water starts the germination process. The rate of water movement into the seed depends on the germination media's texture, media compaction, and proximity of soil-to-seed contact. Seeds have negative water potential, creating a gradient for the water in the soil (which has a high water potential) to move into the seed. Most seed germination media have a fine texture that constantly provides water to the seed as it is taken up.

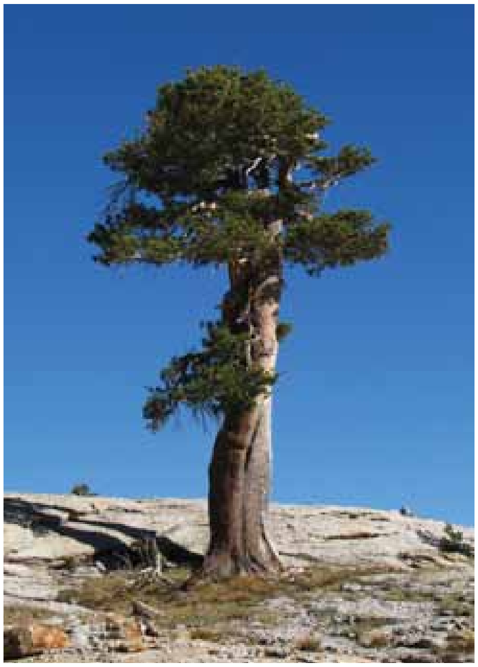
Seed ***priming*** is the process of hydrating and then drying out a seed for greater germination rate and uniformity. Seeds are allowed to imbibe water and continue into the lag phase of early germination but halted before radicle emergence. Seeds are then dried to nearly their original water content. Primed seed storage may be shorter, and the benefits of priming may be lost if seeds are stored for too long. Seed priming is commercially used for crop production of bedding plant plugs where uniform germination is critical to profits. ***Plugs*** are seeds that are grown in small containers to transplantable size, **Figure 13-5**.

photoiconix/Shutterstock.com

Figure 13-5. The seeds of bedding plant plugs are often primed and planted with machinery to ensure uniformity.

Oxygen

Oxygen is required for respiration of germinating seeds. Gas exchange between the germination medium and seed embryo are necessary for rapid and uniform germination. Seed beds can become saturated due to heavy rains or irrigation. These beds will have limited oxygen available to seeds and result in poor or reduced germination rates.



Tom Grundy/Shutterstock.com

Figure 13-6. The lodgepole pine requires the high temperatures of a fire to melt away the resin that covers the cone in order to release seeds.

Hardyplants at English Wikipedia

Figure 13-7. The seed coat of the Kentucky coffeetree can be as thick as two millimeters.

Light

Light quality and photoperiod play a role in seed germination, particularly as it relates to dormancy. Light-sensitive species have a dormancy that requires light in order germinate. Many of these plant species evolved to survive in shallow soils. Examples include begonia, *Calceolaria*, coleus, *Kalanchoe*, primrose, and African violets. Germination is inhibited by light in some species, including *Allium*, amaranth, and phlox.

After seedlings have emerged, high levels of light are important for sturdy and vigorous transplant growth. Low light levels produce reduced photosynthesis rates and poor seedling growth. Supplementary lighting often fulfills these lighting needs for seedling growth.

Seed Dormancy

Once harvested, most seeds only require favorable temperatures and water for germination to occur. These seeds are considered quiescent. Other seeds have a physiological adaptation that allows seeds to delay germination, called *seed dormancy*. Dormancy allows a seed to germinate only when environmental conditions favor seedling survival. For temperate species, this often requires a moist, chilling period (winter conditions) before germination in the spring. Some species require extremely high temperatures before germination, **Figure 13-6**. Desert species can survive long droughts, and then germinate after a rain. This kind of dormancy is called *primary dormancy*, and it occurs as the seed is shed from the plant.

When quiescent seeds or seeds that have emerged from primary dormancy are exposed to an extreme stress of drought, high temperatures, or low oxygen levels, they can become dormant. This is called *secondary dormancy* or *induced dormancy*. It provides a survival mechanism for seedlings if adverse environmental conditions are present. Some species even have a double dormancy and require multiple treatments to germinate.

Seed Coat Dormancy

The seed of the Kentucky coffeetree has a hard, bony seed coat that resists any efforts by water to penetrate, **Figure 13-7**. In nature, these seed coats break down slowly over time through exposure to weather, microorganisms, or other substances. In horticulture, the process of physically removing part of the seed coat to allow imbibition is called ***scarification***.

Many horticultural species require scarification. Scarification methods include:

- Mechanical scarification. Seed coats are chipped or weakened (but not damaged) by rubbing with sandpaper, scraping with a file, or cracking with a vise or hammer. Large-scale commercial operations may have a drum lined with sandpaper that removes the seed coats of small seeded legumes, such as clover or alfalfa.
- Chemical scarification. Sulfuric acid is used to wear away the coat of hard seeds. Seeds are placed in an acid bath for a predetermined amount of time and then rinsed with water to remove any residual chemicals. Seeds are sown immediately after treatment.
- Hot water scarification. Seeds are placed in a large amount of 170°F to 212°F (77°C to 100°C) water. This softens the seed coat to make it pervious to water. In this process, the water is heated, and then the seeds are placed in the water. Finally, the heat source is removed. Seeds are kept in the water between 12 and 24 hours and planted shortly thereafter.

"Behold, my brothers, the spring has come; the earth has received the embraces of the sun, and we shall soon see the results of that love! Every seed has awakened, and so has all animal life."
—Sitting Bull

Chemical Dormancy

Natural chemicals that accumulate in fruit and seed coat tissues can inhibit germination or reduce gas exchange in seeds. Some fleshy fruits such as citrus, cucumbers, apples, and pears contain substances ranging from ***phenols*** (naturally occurring chemical compounds in seeds) to ***abscisic acid*** (a plant hormone) that inhibit germination. Some seeds are coated with a chemical inhibitor that is only removed through leaching after heavy rain, including iris and some desert plants. In other seeds, such as spinach and white mustard, a layer of mucilage (a thick, gluey substance) hampers gas exchange and limits seed germination, **Figure 13-8**.

Eugene Gurkov/Shutterstock.com

Figure 13-8. The seeds of heirloom tomatoes are covered with a mucilage layer that must be removed before sowing.

Morphological Dormancy

Some seeds are not mature when they fall from the plant. In these seeds, the embryos have not fully developed before dropping. This condition can be found in a wide range of species, including anemone, poppy, ginseng, carrot, rhododendron, primrose, and others. To promote germination in these seeds, a temperature treatment (of either cold or warmth depending on the species) may promote germination.

Physiological Dormancy

The embryo controls physiological dormancy of seeds and delays germination. This increases the time for growth of the radicle to force open the seed covering. This dormancy can be overcome by manually removing the seed covering. Species such as lettuce, pepper, tomato, redbud, and lilac have demonstrated this kind of dormancy. ***Photodormancy*** occurs when seeds either require a period of light or dark conditions to germinate. Some seeds need after-ripening or time in storage to mature. This dormancy is not long lasting and can be broken with chilling treatments.

Corner Question

Q What is the largest seed in the world?

Stratification

Intermediate and deep physiological dormancies require multiple months of moist, aerated cooling for seeds to germinate. This horticultural practice is called *stratification*. Seeds are stored in a moist, aerated medium at specific chilling temperatures for a designated amount of time. Depending on the species, stratification may last from one to five months. Many woody shrubs and tree species require stratification treatments. Some temperate, tropical, and semitropical species need a warm stratification treatment. In this practice, rather than providing cool temperatures, warm temperatures are paired with a moist, oxygen-rich medium to stratify the seed.

Seeds can be stratified outside in the fall. Seeds can be planted in a ***seedbed*** (a specially prepared space for seed germination) or in a cold frame. The wet, winter months will provide an environment that releases dormancy. However, seeds need to be protected from freezing, drying, and rodents. Many horticulturists will use refrigerated stratification for small batches of seed or high-value seed. Seeds are usually soaked for 12 to 24 hours and then planted in media such as sand, peat moss, vermiculite, or composted sawdust. A typical media mixture might have a 1:1 ratio of sand to peat or a 1:1 ratio of perlite to peat. Seeds can be stratified in layers to use space efficiently and placed in a container that limits drying and provides suitable aeration. Stratification temperatures usually fall within a range of 33°F–50°F (1°C–10°C). Once the specified time has passed, a few seeds are planted to see if germination occurs. When ready, seeds can be gently screened through a sieve and planted immediately.

Seed Propagation Techniques

Most agronomic, forestry, and vegetable and bedding plant growers propagate plants by seed. Depending on the crop, seeds can be sowed directly in the field, started in a greenhouse for plug production, or grown in nursery transplant beds to produce bare-root plants. Seed propagation requires an understanding of the germination requirements for each species grown. Four factors to consider for successful germination include:

- High-quality seed—needed for good germination percentage, rates, and uniformity.
- Seed selection of cultivars—select species that hold the desired characteristics for production.
- Seed dormancy—can be managed through treatments or sowing timing.
- Favorable environmental conditions—include the proper temperature, available water, oxygen, and light or dark conditions.

Field Seeding

Directly sowing seeds into the soil is the most common practice for commercially produced agronomic crops, many turfgrasses, vegetables, and some woody trees and shrubs. Many home vegetable and flower gardens are directly sown as well. Field seeding can be less expensive than using transplants, but variable environmental conditions can make it challenging to achieve uniform germination. Factors such as good seedbed preparation, high-quality seed, proper timing of planting, and seed treatments optimize the potential for good germination and seedling growth.

Seedbed Preparation

Good seedbeds have a soil texture and structure that provides adequate water contact with the seed, proper drainage and aeration, and minimal crusting. Large clumps or clods of soil should be removed. To prepare large seedbeds, use tractors with attachments to till and crumble the soil. In the home garden a tiller, spade, or rake can do the same thing, **Figure 13-9**. Building up the soil can provide nutrients and organic matter for soil structure.

vitaga/Shutterstock.com

Figure 13-9. A tiller can be used to till and crumble the soil in the same manner as a field tractor.

High-Quality Seed

Seed purchased from a reliable, certified seed dealer ensures commercial growers are planting seeds that have been tested for pureness of stock, have no weed seeds, and will uniformly germinate. Most seeds are hybrid seeds that offer high germination rates and vigorous, healthy seedling growth. Many home gardeners or hobbyists will save seeds, offering an inexpensive way to grow plants each year.

Timing of Planting

Each crop has its own environmental requirements, and proper soil temperature plays a key role in germination success. Research the need of each crop and create a planting calendar based on local conditions. For many crops, cool soil temperatures will result in uneven and poor germination and can cause stunted growth. High soil temperatures may induce ***thermodormancy***, a secondary dormancy that inhibits germination.

Seed Treatments

Many diseases can impact seeds sown directly into the field. Some commercial growers use seeds that have been pretreated with a chemical fungicide to minimize disease risk. Priming is another practice that gives some seeds a head start toward faster germination rates and increased uniformity. Some seeds are small, so they are coated with a kind of clay through a process called *pelleting*. This process increases their size and allows them to flow through mechanical planters or be planted by hand, **Figure 13-10**.

Dwight Sipler, Stow, MA

Figure 13-10. Pelleting seeds changes their size and shape for improved mechanical planting. The lettuce seeds on the right are not coated. The coated seeds (on the left) are much easier to handle and may be planted by machine or by hand.

Planting Depth

The correct planting depth has been determined for most horticultural crops. Proper planting depth ensures that seeds will be able to emerge from the soil and establish themselves quickly. Seeds sown too deeply may rot in the soil or have staggered emergence. If the planting depth is too shallow, seeds may dry out or be washed away. A general guideline is to plant a seed to a depth about three to four times the diameter of the seed. Seeds that require light for germination are planted at a shallow depth and moisture levels are monitored.

li jianbing/Shutterstock.com

Figure 13-11. As seeds, these carrots were planted too closely. Crowding like this results in small roots for harvest.

Spacing

Appropriate seed spacing use the field area efficiently and maximizes yields. Seeds that are sown too closely can compete with each other for nutrients, water, and light, **Figure 13-11**. Seeds sown too far apart allow for weed growth and waste space. Many field-sown seeds are planted with a mechanical seeder that precisely plants seeds to optimal rates and depths.

Equipment

Mechanical seeders increase the efficiency of planting vegetable and agronomic crops. Seeders vary widely. They are selected based on the size and shapes of the seeds to be sown, soil properties, amount of land, and precision with which seeds need to be placed in a row.

Seeders have three main components. The seed hopper contains the seeds, a metering system measures out the number of seeds, and a drill places the seed in the soil. A seed drill might place seeds into an open furrow or punch individual holes in which to place the seeds. Random and precision seeders are available. Random seeders sow seeds without exact spacing but at a specified rate determined by the size of the seeding wheel and speed of the tractor, **Figure 13-12**. Precision seeders maintain a designated spacing and can use considerably less seed. Precision vacuum seeders use a vacuum to pick up a single seed and set it into the soil.

pryzmant/Shutterstock.com

Figure 13-12. This grass seed spreader is an example of a simple mechanical spreader.

Watering

All seeds require adequate and consistent moisture for germination and early seedling growth. Many growers provide supplementary irrigation through overhead sprinklers, subsurface flooding, or drip irrigation. Natural rainfall also provides ample moisture in many areas of the country. Seeds are watered regularly to limit any soil crusting that might occur.

Field Nurseries

Many nurseries produce their own woody transplants, fruit and nut tree rootstock plants, and vegetable transplants. Many of the practices employed in direct field seeding are used in field nurseries as well. However, woody transplants can initially be spaced very close together as they will be harvested and sold as bare-root plants for transplant into pots. Woody transplants require more controlled management to ensure their successful transplant into potted production.

STEM Connection

Squirting Cucumbers

The squirting cucumber (*Ecballium elaterium*) is related to pumpkins, squash, and gourds. This nonedible, poisonous cousin is a fascinating vegetable curiosity. As it grows along the ground, the vine forms a prickly, fleshy fruit. As the fruit matures, the slightest touch or tremor will launch a burst of mucilaginous liquid that contains its seeds. This dispersal travels at an amazingly fast speed. *Ecballium elaterium* is native to Europe, northern Africa, and some areas of Asia.

flaviano fabrizi/Shutterstock.com

Field Nursery Seedbeds

Nursery seedbeds have well-drained soil with a loamy texture. They are often incorporated with other crop rotations, including cover crops that provide nutrients and improve soil structure. Seedbeds are typically 3 1/2′–4′ wide with walkways in between. This spacing allows workers to reach easily into the middle of the bed to pull weeds.

Timing of Planting

The timing of crop planting is similar to field seeding. Sowing should occur based on the environmental requirements of the particular crop. In woody plant production, many seeds will need to be scarified and or stratified for optimal germination. For woody plants that remain in the seedbed for a year or more, moisture, shade, nutrients, and weed and disease control must be carefully applied. Transplants that are ready to be harvested might be pulled mechanically and sold as bare-root plants. Many vegetable transplants used to be grown this way. However, they are now usually grown as plugs in a greenhouse.

Greenhouse Production

Greenhouses offer controlled conditions that are ideal for seed germination, proper temperatures that protect plants from freezing or chilling injuries, consistent watering, and soilless potting media for drainage and aeration.

Most commercial growers now specialize in producing plugs for transplants. The transplants are sold to retail nursery and greenhouse operations where they continue to grow prior to sale, **Figure 13-13**.

DutchScenery/Shutterstock.com

Figure 13-13. These geranium plugs will be shipped to a retail nursery where they will be potted into larger containers and sold to home gardeners.

Before the shift to plug production, growers would plant seeds in flats or germination trays. After a short period of seedling growth, they would then transplant the seedlings into cell packs, into individual containers, or directly into the ground. This method is still used by some small operations, botanic gardens, and home gardeners.

Plug Production

Millions of bedding plants, perennials, and vegetable plugs are produced each year in greenhouses that provide ideal germination and seedling growth conditions. Plug production has become a specialized industry. Growers invested in equipment that carefully manages germination conditions. Plugs can be grown in as little as six to eight weeks, allowing for multiple crops per season and fast shipping to clients. Plugs are transplanted to larger containers using the soil in which they were grown, reducing symptoms of transplant shock.

A plug seedling is grown in a small amount of soil in a small cell that is part of a large plug tray. A tray may have as many as 220–800 plugs. Much of soil building and seeding process is done by specialized machines. When using mechanical seeding, it is important to use high-quality pelleted or primed seeds to ensure even germination.

Seedlings have four distinct, observable stages of growth, **Figure 13-14**:

- Stage 1—radicle emergence or protrusion.
- Stage 2—cotyledon spread.
- Stage 3—three or four leaves unfolding.
- Stage 4—more than four leaves present.

At each of these stages, environmental conditions are controlled to maximize growth. Many plug producers use special germination chambers that provide proper lighting, temperature (70°F–75°F [21°C–24° C]), and humidity in stage 1.

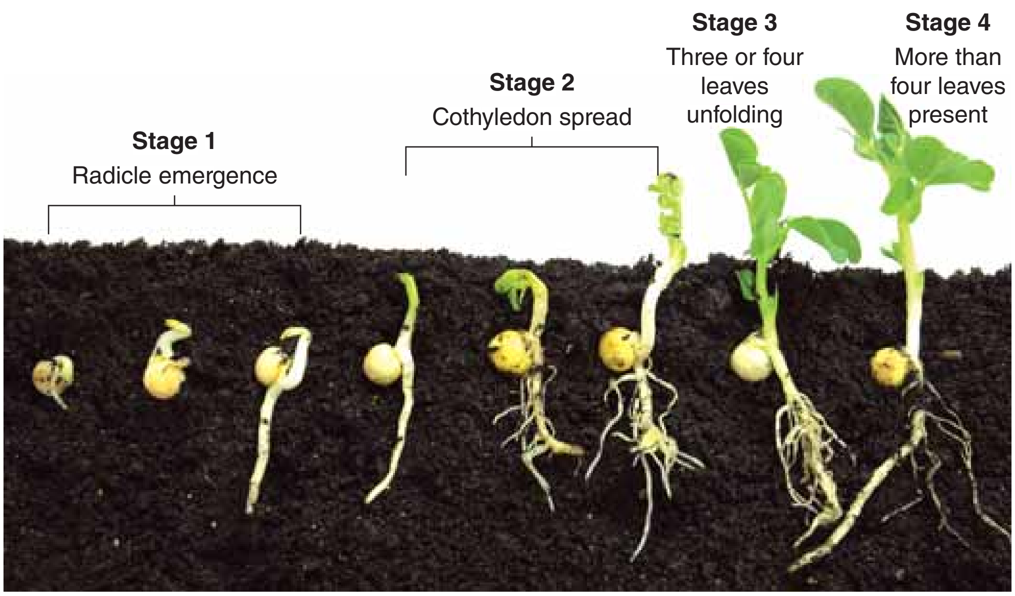
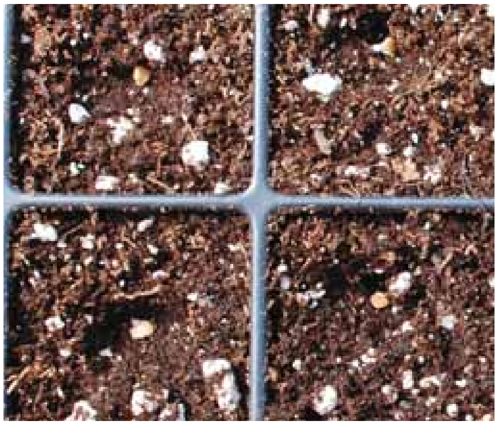


Figure 13-14. Seedlings have four distinct, observable stages of growth.

Plugs are often misted or fogged to maintain moisture and humidity. Humidity levels need to be carefully controlled to limit foliar disease. Light should be increased in stage 2 to prevent shoot (hypocotyl) elongation. Fluorescent or high-pressure sodium supplemental lighting in stage 2 and early in stage 3 provides sufficient intensity for growth. Nutrients should be available and then somewhat minimized to harden off seedlings for transplanting. Plugs are ready to be transplanted or shipped at stage 4. Many large-scale operations will have a mechanical transplanter that transfers plugs to bigger containers.



Julie Clopper/Shutterstock.com

Figure 13-15. This soilless potting media has very fine particles of peat moss and vermiculite to ensure soil-to-seed contact as well as adequate moisture retention/drainage, oxygen levels, and nutrients.

Media

Germination media is different than media used for other parts of potted plant production. Germination media has a fine texture to ensure soil-to-seed contact, moisture retention and drainage, adequate oxygen levels, and nutrients. The structure must also provide support for the seedling, **Figure 13-15**. Typical media components include fine-textured peat moss, perlite, ground bark, vermiculite, and slow-release fertilizers. The media should be sterile to prevent disease. Different textures are used depending on seed size. For example, a small petunia seed needs a finer textured germination media than a larger cockscomb seed.

Mechanical Seeders

Mechanical seeders are a significant financial investment for greenhouse operations, but using them increases efficiency and reduces labor costs. Mechanical seeders may broadcast seeds across a flat or they may plant precisely, as in plug production. There are three types of seeders: template or plate, needle, and drum seeders. Template seeders use a metal plate with holes drilled into it, **Figure 13-16**. A vacuum in the seeder pulls seeds to attach to the template. Then when the vacuum is released, the seeds fall into the flat. Different seed sizes require different templates, making this a cumbersome option. It is, however, the least expensive option. A needle seeder has individual needles that lift seeds and place them into individual cells in a flat. The needles come in different sizes, are moderately priced, and can sow up to 100,000 seeds an hour. The drum seeder has a rotating cylinder that uses a vacuum to pick up seeds. As the drum rotates, seeds are deposited into the germination media. It is the fastest and most precise seeder, sowing as many as 800,000 seeds each hour. It is also the most expensive seeder.

Photograph by Graham Goodenough

Figure 13-16. This automatic needle seeder can be adjusted to sow different sized seeds.

Prairie Drifter Farm

Figure 13-17. This germination chamber provides high humidity for emerging seeds.

Watering

Early stages of seedling growth need high levels of humidity and moisture. Humidity can be controlled through specialized germination chambers. On a smaller scale, germination tents may be used. These tents are made by placing seed flats on a greenhouse bench and covering them with polyethylene plastic, **Figure 13-17**. These chambers or tents prevent the seedlings from drying out in early stages of growth. Growers must provide ventilation in the chambers, however, to minimize risk of heat buildup.

As transplants begin to grow, they may be moved to a greenhouse. Here water can be delivered using a mist nozzle on a hose. Automatic boom misters have many nozzles that travel the length of a greenhouse, **Figure 13-18A**. Many greenhouses have subirrigation systems. Flats are placed directly on the concrete (which usually provides bottom heat). Water floods the floor and passively drains back into a water reservoir, **Figure 13-18B**. Nutrient solutions can be easily delivered through the water in this method. Capillary mat systems are made of a fabric that holds water when saturated and releases it to the flats as it is wicked up. These can limit evaporation and water loss, conserving water resources. Some operations use a float bed, similar to those used in the production of tobacco transplants. Styrofoam trays with individual cells are planted with seeds and placed on a nutrient-rich water solution, **Figure 13-18C**.

Transplanting

When stage 4 is reached, seedlings are ready to be hardened off and transplanted. Temperature and moisture are reduced to make seedlings ready to move and reduce symptoms of transplant shock. Transplant shock can result in premature stalk formation, increased susceptibility to disease, and diminished yields. Transplanting has historically been done by hand, but there has been a recent, significant shift to mechanized transplanting.

A *vallefrias/Shuttsrstock.com* **B** *T.W. van Urk/Shutterstock.com* **C** *Photograph by Matthew Vann*

Figure 13-18. A—Automatic boom misters travel the length of the greenhouse. B—Flood floors in greenhouses conserve water, deliver bottom heat, and maximize space for young seedlings. C—These tobacco float trays sit in a nutrient solution that provides constant moisture to germinating seeds.

The container the plants are transplanted into will have holes made in the media, either manually or mechanically, using some form of a dibble, **Figure 13-19**. The roots are tucked into the hole in the media, and soil is packed gently around the plant. Transplants are allowed to continue growing to more a substantial size or are hardened off to be moved outside.

stockcreations/Shutterstock.com

Figure 13-19. Dibbles can be simple tools for home gardeners or mechanized tools used in greenhouse transplanting operations.

Seed Selection

Modern agricultural systems rely on the production of high-quality seeds. The majority of agronomic crops, annual bedding flowers and other ornamentals, and vegetables are propagated each season from seeds. Seeds hold the genetic traits incorporated by breeding and selection to create cultivars. These cultivars are adapted for specific environments and will yield a marketable and profitable crop. Customers demand that the products they buy represent the description that has been offered. Therefore, the genetic identity and purity of seeds forms the foundation for overall seed quality.

Using genetically pure seed, a grower or gardener can be assured that the seed is:

- True to name—seeds are labeled correctly with appropriate species, cultivar, and history.
- True to type—seeds grow into visual standards specific to the cultivar or species as it is labeled.
- Free of contaminants—little or no presence of weed seeds, no seedborne diseases, no seeds of other genetic material.

A variety of seed types are available to growers and gardeners. The seed that is used depends on the production goals and philosophy of the grower.

Landraces

Humans have long selected seeds from plants that showed promising characteristics. Seeds are saved from part of the harvested crop to be used the following growing season. A ***landrace*** is a locally adapted or traditional variety of a plant. Landraces maintain a tremendous genetic diversity that serves as an inherent buffer against environmental stresses, insects, or diseases that may afflict the crop. Landraces have adapted to local conditions and are still used in some parts of the world, **Figure 13-20**.

D Pimborough/Shutterstock.com

Figure 13-20. The Irish government is dedicated to preserving landraces such as potatoes and other grains. Each of these plants has a stable set of unique genetic characteristics.

Landraces are open-pollinated, which means that pollination occurs by insect, bird, wind, humans, or other natural mechanisms and the flow of pollen between individuals occurs freely. Heirloom varieties are also open-pollinated species. These varieties have been selected and saved by gardeners over generations. Somewhat less diverse than a broad landrace, heirloom varieties have enjoyed resurgence in recent years.

Corner Question

What type of seeds do you eat?

(Need credit line from author)

Figure 13-21. Heirloom varieties, such as Cherokee Long Ear corn, have been passed through generations and often have traits that cannot be found in hybrid seeds.

They have traits such as intense flavor, shapes, and colors that are not always present in hybrid seed, **Figure 13-21**. Heirloom seeds can be saved from one generation to the next without losing characteristics and performance of that variety.

Modern farms have shifted to hybrid varieties that tend to be uniform, produce high yields, and respond to the mechanization used on many farms. Many scientists are concerned that hybrids have led to a loss of genetic diversity. Conservation efforts are being made to maintain ***germplasm*** repositories (seeds or other materials from which plants are propagated). These repositories of landraces and other open-pollinated seeds can serve as raw genetic material for future use.

Wild Populations

Most native plant species evolve over time into populations with a fairly uniform phenotype (outward or observable properties of an organism) and genotype (inherited genetic properties), which are adapted to local environmental conditions. If a species has a broad geographic distribution, populations may look the same (have the same phenotype) but vary genetically to adapt to different areas. For example, wild common beans (*Phaseolus vulgaris*) are found throughout Central and South America. Different populations of wild beans show varying degrees of drought tolerance depending on their location. Plant breeders will sometimes draw from wild populations to improve traits in their breeding lines.

Some plants found in the wild may show a phenotypic difference in their morphology (size, shape, or structure). These plants are called botanical varieties, or simply varieties. For example, Alabama cherry (*Prunus serotina* var. *alabamensis*) is a variety of black cherry (*Prunus serotina*). Other botanical variations of black cherry also exist, including var. *eximia*, escarpment cherry; var. *rufula*, southwestern black cherry or Gila chokecherry; and var. *salicifolia*, the capulin black cherry. Most varieties can be produced by seed and are true to type, meaning they will display the characteristics of the parent plants. White flowering redbuds, a popular, woody, landscape ornamental, is a variety (*Cercis Canadensis* var. *alba*) and can be planted from seed, **Figure 13-22**.

Sam Aronov/Shutterstock.com

Figure 13-22. White flowering redbud is a botanical variety of common redbud and produces seeds that will grow and also have white blooms.

The botanical form, or forma, is a secondary taxonomic rank. Form members usually have only slight physical differences, such as leaf color or leaf shape. They occur at any point within a species' range. Forms can be determined based on environmental factors rather than genetic factors. They can come from a sport or other mutation and are usually vegetatively propagated. Some forms have horticultural value, such as the thornless honey locust.

Gleditsia triacanthos forma *inermis* is a form of the usually very thorny honey locust, **Figure 13-23**.

Sally Wallis/Shutterstock.com

Figure 13-23. The thornless honey locust is a form of the spiny honey locust and must be propagated vegetatively.

Hybrids

Many annual bedding plants and other ornamentals, vegetables, and agronomic crops are hybrid varieties, produced by plant breeders and sold as seed. As discussed in Chapter 8, plant breeding is the process of cross-pollinating parent plants to create progeny that display desired characteristics. Commonly desired characteristics include increased disease resistance, novel flower colors, and improved vigor and yield. Hybrid plants have a quality called hybrid vigor, which results in improved growth performance. The seeds that result from hybrid plants are not saved because they are not true to type. Plants grown from these seeds may lose many of the traits of the cultivar.

Transgenic Cultivars

Transgenic describes an organism into which genetic material from an unrelated organism has been introduced. Transgenic cultivars have a genome that has been transformed by genetic engineering. Also known as a ***genetically modified organism (GMO)***, the plant has been transformed for a variety of reasons including resistance to disease, herbicides, or insects. Many agronomic crops, such as corn, soybean, and cotton, have been transformed to hold a Bt gene from the bacteria *Bacillus thurinigiensis* to produce a toxin that fights off pests. Other crops have genes that are resistant to an application of herbicide (glyphosate), making weed control more efficient on a large scale. In Florida, citrus greening is a severe and devastating disease. It can destroy entire orchards. Promising research shows that a gene from spinach inserted into an orange plant can result in disease resistance. Not all genetically modified plants have outside genes inserted into their tissues. In the case of the Arctic® apple, the apples' own genes have been modified to turn off the expression of a chemical that causes apples to turn brown.

There is considerable debate by consumers over transgenic plants. Concerns for gene contamination across fields, food safety, and other arguments have slowed widespread acceptance of this technology. Palmer amaranth is an aggressive weed that has been a serious problem in fields in the southeast United States. Herbicide resistant GMO cultivars managed to rid this weed from fields for many years. Many scientists believe that transgenic plants may be one tool used along with other strategies to manage pest problems. Others disagree or question the use of this biotechnology.

Did You Know?

The seed case that holds kapok tree seeds are filled with soft, fluffy material. This material was previously used as filler for life jackets or bedding because it is light, strong, and waterproof.

Seed Production

To ensure production of high-quality seeds, commercial seed producers follow a set of state and federal guidelines to produce seeds that are certified.

Certified seed have a specific legal definition set by the Federal Seed Act, which sets strict standards for seed growers selling nationally. Most states have additional seed laws that govern the labeling, sale, and transportation of agricultural, vegetable, and other seeds.

The seed certification process is intended to protect growers and gardeners by ensuring that they are purchasing seed that has the following characteristics:

- Seeds free of contaminating material, including noxious weed seeds, stones, fungi, soil, chaff, broken seed, and other debris.
- Seeds with genetic identity and purity. The cultivar or variety is true to the given description.
- Seeds with germination uniformity.

Seed producers practice strict field and equipment sanitation to minimize any seed contamination by weeds, disease, and other material. They usually grow seeds in isolated fields to minimize any cross-pollination by other genetic material. Throughout the growing process, seed inspectors from local governmental agencies visit the fields to ensure varietal purity, isolation, and freedom from weeds and diseases. After harvest, seed is properly cleaned, extracted, and stored in separate bins labeled with the type, variety, year produced, and field location. Seeds are sent to a seed testing lab and tested for the characteristics from the list of characteristics. This service is often performed by state departments of agriculture. If seeds meet these standards, they can be distributed and sold. The state regulatory agency has the authority to stop the sale of seeds that are found to be mislabeled or misrepresentative of the variety.

Plant Variety Protection Act

The Plant Variety Protection Act (PVPA) of 1970 (amended in 1994) provides plant breeders legal intellectual property rights protection to new varieties of plants that are sexually reproduced (by seed) or tuber-propagated. Breeders are issued a Certificate of Protection that gives them exclusive rights to sell, reproduce, import, export, or use the plant in producing a hybrid or different cultivar. The protection lasts up to 25 years and enables plant breeders to recover research costs. It also provides an incentive for grower to develop improved varieties.

A variety can be patented if it is:

- New material that has not been sold prior to the application.
- Distinguishable from any other existing variety.
- Uniform with any variation being describable, predictable, and commercially acceptable.
- Stable and when reproduced remains unchanged according to its distinctive characteristics.

According to the language written in the PVPA, the act is intended "to encourage the development of novel varieties of sexually reproduced plants and to make them available to the public, providing protection available to those who breed, develop, or discover them, and thereby promoting progress in agriculture in the public interest." Varieties that are protected under the PVPA can be sold as seed stock only with the permission of the holder of the Certificate of Protection.

Seed Saving

Seeds should be harvested when the embryos are relatively mature. Immature seeds may result in little or no germination. If germination does occur, the seedling often emerges as weak or stunted. Immature seeds tend to have high moisture content, watery endosperm, and a light-colored seed coat. They tend to rot in storage and usually shrivel when dried.

Mature seeds come from fully ripe fruit and should be collected before the seed disperses, **Figure 13-24**. Ripeness appearances vary dramatically depending on species. Generally, ripe fruit will show color changes, chemical changes (such as in sugar or starch content), and shifts in specific gravity. Many gardeners know that seeds that float are usually not viable. Scientists use this same test to measure the specific gravity of seeds in comparison to the known specific gravity of water. Viable seeds are usually denser than nonviable seeds.

Przemyslaw Wasilewski/Shutterstock.com

Figure 13-24. Poppy seeds should be harvested when the fruit is mature, but before the seeds disperse.

Because seeds are harvested before dispersal, they must be extracted from their fruit. In some cases, the fruit is dried and the seeds fall out. Old flower heads of cockscomb or celosia can be placed upside down in a paper bag to dry. Once dried, the plant can be shaken, or threshed, to remove the seeds. The seeds are then sorted through sieves to separate them from the chaff. Seeds contained within fleshy fruit, such as raspberries and strawberries, can be macerated using a blender filled with water. The pulp is skimmed and rinsed to extract the seeds. In tomatoes, the pulp is separated from the juice and the seeds. The seeds are coated with a mucilage layer that must be removed through an acid treatment or fermentation. Once removed, the seeds can be rinsed and dried for storage.

Some seeds, such as a number of grasses, may require stronger mechanical force to extract the seeds. Hammer mills, threshers, and other machines are used to separate seed from fruit. Seeds such as some pines and conifers require high heat to remove them from the cone. They should be placed in a special kiln to dry the cone and coax it open.

After seeds have been removed from the fruit, they need to be separated from the chaff, insect parts, soil, and other foreign material. Most commercially harvested seeds use a set of sieves to isolate the seeds by blowing air through the screens. The sieve screens come in various sizes that are used to clean and grade the seeds, **Figure 13-25**.

ansem/Shutterstock.com

Figure 13-25. Seed sieves remove chaff, soil, rocks, and other unwanted material from harvested seeds.

Seed Storage

Seeds are living, respiring organisms. Placing them in the right environmental conditions will lengthen their shelf life. For most seeds, every 10% drop in moisture content (within limits) will double the length of viability. Every 50°F (10°C) decrease in temperature will also double the storage shelf life. Many species can be stored at temperatures of 0°F (–18°C) for a considerable amount of time. Some seeds require added moisture during storage. Citrus, walnut, oak, and chestnut species all prefer a chilled, moist environment. Cool, wet conditions can also encourage the growth of rot-causing fungi. Take precautions to minimize disease risks.

Careers in Seed Propagation

The seed propagation industry provides food and clothing to the world. The majority of human calorie consumption worldwide comes from seeds such as cereals, legumes, and nuts. Many cooking oils are made using seeds. Cotton fiber comes from cotton plant seeds. Seed propagation also provides crops used to feed livestock and beautify the environment. Seed sales representative and nursery propagator are just two careers in the seed propagation field.

Seed Sales Representative

Many seed companies employ sales representative to market their product to retailers, wholesalers, and growers. A seed sales representative is responsible for cultivating relationships with clients to facilitate the sale of seeds. Representatives must understand customer needs and develop trusting relationships with customers. Sales representatives manage forecasting and seed line demand issues. Sales representatives serve as a vital link for technical growing information and can handle any inquiries or complaints regarding a product. Sales representatives usually have an associate or bachelor's degree and significant experience in sales.

Nursery Propagator

Many nurseries specialize in the production of woody trees and shrubs that are produced primarily from seed. Nurseries have covered greenhouse space as well as outdoor growing space for container (plug) seedling production. A propagator is responsible for germinating and growing bare root seedlings and transplants plugs. Production responsibilities include soil mixing, sowing, thinning, irrigation, photoperiod manipulation, and pest control among other greenhouse production practices. Propagators may have to provide seed treatment such as stratification, scarification, and pre-germination techniques to enhance the germination of woody plants. Some propagators have a high school diploma, along with experience. Management and supervisory positions require a minimum of an associate or bachelor's degree.

CHAPTER 13

Review and Assessment

Chapter Summary

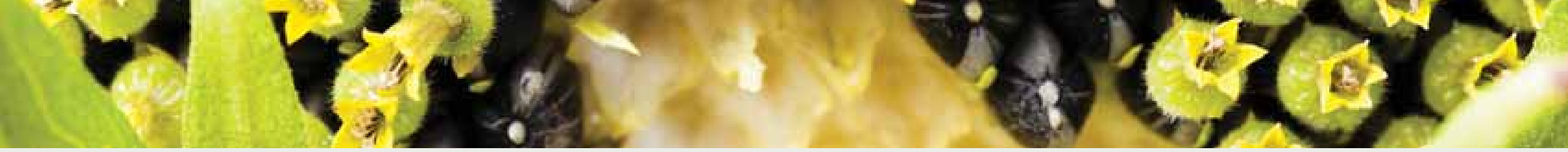
- Seeds are formed as a result of the fertilization process. All seeds have an embryo, a protective outer covering, and storage tissue.
- The three stages of seed of development are histodifferentiation, cell expansion, and maturation drying.
- Some plants are able to spontaneously produce seeds without going through the fertilization process. The process creates genetic clones of the parent.
- In order for germination to occur, the seed must be viable, favorable environmental conditions must be present, and dormancy conditions must be overcome.
- Seed germination has three phases starting with imbibition or the uptake of water, followed by lag phase where cellular activities prepare for seed growth, and then the emergence of the radicle or seed root.
- Temperature, water, oxygen, and light are critical environmental factors in seed germination.
- Dormancy allows a seed to germinate only when environmental conditions favor seedling survival. A hard seedcoat, chemical inhibitors, seed embryo maturity, or light or temperature requirements can cause seed dormancy.
- Four factors needed for successful cultivation include high-quality seed, seed selection of cultivars, seed dormancy, and favorable environmental conditions.
- Field seeding requires proper seedbed preparation, high quality seed, proper planting timing, possible seed treatments, appropriate planting depth and spacing, and adequate water.
- Greenhouses offer controlled conditions that are ideal for seed germination.
- Most commercial growers specialize in producing plugs for transplants. Plugs of bedding plants, perennials, and vegetables can be grown in 6–8 weeks.
- Seedlings can be characterized by four stages of growth: radicle emergence, cotyledon spread, unfolding of three or four leaves, and the presence of four or more leaves.
- Seeds hold the genetic traits incorporated through breeding and selection to create cultivars.
- Seeds come from different places and are selected based on their characteristics. Categories of seeds include landraces, heirloom varieties, wild populations, hybrids, and transgenic cultivars.
- To ensure production of high-quality seeds, commercial seed producers follow a set of state and federal guidelines to produce seeds that are certified.
- The Plant Variety Protection Act provides plant breeders legal intellectual property rights protection for new varieties of plants that are sexually reproduced (by seed) or tuber-propagated.
- Seeds should be properly harvested at maturity, extracted from the fruit, cleaned, and stored at proper temperatures for long shelf life.

Words to Know

Match the key terms from the chapter to the correct definition.

A. abscisic acid
B. apomixis
C. cell expansion
D. desiccation
E. genetically modified organism (GMO)
F. germplasm
G. histodifferentiation
H. imbibition
I. lag phase
J. landrace
K. maturation drying
L. phenol
M. photodormancy
N. plug
O. plumule
P. priming
Q. quiescent
R. radicle
S. radicle protrusion
T. scarification
U. seedbed
V. seedlot
W. thermodormancy
X. transgenic
Y. viable
Z. vivipary

1. A stage of seed development when the embryo and endosperm develop distinct characteristics.
2. A plant hormone that can inhibit germination.
3. The process of hydrating and then drying out a seed for greater germination uniformity.
4. A locally adapted or traditional variety of a plant.
5. A need of some seeds for either light or dark conditions in order to germinate.
6. A specially prepared space for seed germination.
7. A seed that is grown in a small container to transplantable size.
8. Drying out of a seed.
9. The rapid uptake of water by a seed.
10. The ability of a plant to produce seeds without going through the fertilization process.
11. The last period of early seed germination characterized by the emergence of the seed root.
12. Dormant or in a state of inactivity.
13. Alive; a living seed.
14. Seeds of a particular crop gathered at one time and likely to have similar germination rates and other characteristics.
15. A phenomenon in which seeds germinate inside their fruit without maturation drying.
16. A naturally occurring chemical compound in seeds that may prevent germination.
17. Seeds or other materials from which plants are propagated; serves as raw genetic material for future use.
18. A period during seed germination with little or no water uptake but with high cellular activities that prepares the seed to grow.
19. A plant that has had its genome transformed through genetic engineering.



20. A process of removing part of the seed coat to allow imbibition.
21. An organism into which genetic material from an unrelated organism has been introduced.
22. The seed root of a seed.
23. A secondary dormancy that inhibits germination.
24. The growing point for the developing shoot.
25. The phase of seed development when seeds have reached physiological maturity.
26. The second stage of seed development in which seed cells increase in size.

Know and Understand

Answer the following questions using the information provided in this chapter.

1. What parts do all seeds have?
2. What are the three stages of seed development? Briefly explain each stage.
3. What three conditions must be met in order for seed germination to occur?
4. Describe the process of seed germination.
5. What are three indicators of seed germination rates?
6. What is the optimal temperature ranges for plants in the following categories: cool temperature tolerant, cool temperature requiring, and warm temperature?
7. The rate of water movement into the seed depends on what factors?
8. How do light levels affect seedling growth?
9. List the ways seed coat dormancy can be removed.
10. Explain the process of stratification.
11. What are four basic factors to consider for successful germination?
12. Why is it important to use high-quality seed?
13. Why is it important to use the proper planting depth for seeds? What may happen if the planting depth is too deep or too shallow?
14. Why is it important to properly space seeds?
15. Why do plug producers need to know the stages of seedling growth?
16. Name three types of mechanical seeders used in greenhouse production and describe each.
17. What problems can transplant shock cause? What can be done to reduce transplant shock in seedlings?
18. Explain how seedlings are transplanted using mechanized methods.
19. What are landrace plants and why are they important?
20. What are some types of transgenic plants used today?
21. Explain the reasons for genetic modification of plants.
22. What general rights are growers provided under the Plant Variety Protection Act?
23. What are two important concepts for seed storage that increase the length of viability?

Thinking Critically

1. You have collected seeds from different tree species during a recent walk through an arboretum. You sow all the seeds, but not all of them germinate. What do you think is happening? What can you do to get the seeds to germinate?
2. You really love blueberries. You have a blueberry bush in your garden that produces many berries for harvest, but the flavor is not very strong. What could you do to create better tasting blueberries?

STEM and Academic Activities

1. **Science.** Most plant species have different germination requirements. Research a plant that you find interesting and write a report that summarizes your findings.
2. **Engineering.** As a greenhouse grower in the Southwest, water is a valuable resource. Design a watering system that would allow you to maximize your watering efficiency and use for plug production.
3. **Math.** You are a large commercial vegetable grower in the Southeast and need to maximize your space and production timing for optimal profits. Create a planting plan that accounts for growing seasons in the fall, spring, and summer, along with spacing and rotation of at least five crops.
4. **Math.** As a small nursery operator, you have a limited budget of $500 to purchase seeds that you will plant in your field seedbeds. You want the greatest diversity of seeds with enough of each species to be able to sell. You have five seedbeds and each is 25 yards long. After researching the cost of materials and the growing requirements, create a plan for how many seeds you can purchase and how many plants you can grow.
5. **Language Arts.** Imagine that you are the marketing director for an heirloom seed company that grows and sells flowers and vegetable seeds. One of your job responsibilities is to write articles for the grower's information center. Write an article about how to choose the best heirloom seeds. Focus on the characteristics of at least three different types of seeds.

Communicating about Agriculture

1. **Reading and Writing.** The ability to read and interpret information is an important workplace skill. Presume you work for a well-known, successful seed propagation company. Your employer is considering pitching a proposal to the local college to supply propagation needs for various research programs. He wants you to evaluate and interpret some research on innovative seed propagation techniques. Locate three reliable resources for the most current research on seed propagation of native plants in your region. Read and interpret the information. Write a report summarizing your findings in an organized manner.
2. **Reading and Listening.** In small groups, discuss the main topics in the chapter. Ask questions of other group members to clarify concepts or terms as needed.

SAE Opportunities

Peter Bernik/Shutterstock.com

1. **Exploratory.** Visit a plug producer and observe each step of the process. Why do you think so many stages are mechanized? How does this help with germination uniformity?
2. **Exploratory.** Create a germination calendar for your garden plants. What seeds do you need to begin in the greenhouse? What seeds can you sow directly? Include planting timing, depth, and spacing for each plant. Why do you think growers develop planting calendars?
3. **Experimental.** Conduct a germination experiment using your favorite tree or shrub. What environmental conditions will you use? Do you think your plant has any dormancy requirements? What do you expect to observe? How will you collect data? Share your findings with your class.
4. **Exploratory.** Job shadow someone from your state Crop Improvement Association. What are his or her daily tasks? What is the scope of his or her responsibilities? Why do you think the work is important for growers in your state?
5. **Placement.** Visit a local plant conservation society or a garden that collects seeds. Volunteer to harvest, extract, and clean seeds. Many organizations conserve native wildflower seeds. Why do you think this is important?