Improving Success Starting From Seed

Introduction to Germination

A basic understanding of seed germination fundamentals helps gardeners be more successful growing seedlings, regardless of their experience level. Knowing the fundamentals provides an understanding of the "whys" behind the "hows" when starting plants from seed. Remember that seeds are living organisms even before they germinate and begin growing!

Seed germination involves several steps. First, seeds absorb water, in a process called "imbibition." Imbibition is a physical process that occurs whether a seed is dead or alive. Seeds need moist conditions to take up water. This is why it is important to keep the growing medium consistently and evenly moist while seeds are germinating and to ensure there is good contact between the growing medium and the seed. It is also a reason that storing seeds at low moisture content is important to prolong their storage life.

After imbibing water, biological processes speed up inside the seed, activating enzymes and mobilizing nutrients to fuel the growth of the initial root, or "radicle." This internal activity increase seed respiration and the need for oxygen.

The main way that oxygen becomes limiting for seeds is when the media is completely water saturated, particularly if the seed is covered with media. Too much water displaces oxygen in the media. Low oxygen levels stress seedlings, reduce growth, and promote disease. This is the reason that using a seed starting mix that holds moisture, but also drains well, is so important.

Once a seedling's cotyledons expand, it begins to create its own food from sunlight via photosynthesis. As the true leaves develop, nutrients stored in the cotyledons are transferred to actively growing parts of the plant and the cotyledons yellow and drop off.

Seed Storage

For maximum storage life, store seed in dark, cool, dry conditions. The general rule is temperature plus relative humidity should equal 80. A common environment is 40°F and 40% RH. One way to keep humidity low is to store seed in sealed containers with a drying agent like silica gel or an inch of dry rice.

Germination Key Factors

The three primary factors that regulate seed germination are: **moisture, temperature, and oxygen**. **Light** also has an important influence on germination in some species.

Moisture in adequate amounts is critical during germination and seedling growth. Most species need consistently moist conditions until the radicle emerges. As seedlings grow, they become more tolerant of fluctuating moisture levels, so the media should dry out more between waterings.

Water quality is important. Avoid using water that is treated with a water softener, as it can contain salts that are damaging to plants. City water that is chlorinated can be allowed to sit in an open container or bucket overnight to remove the chlorine. Luke warm water is ideal, as very cold water can stress seedlings.

How water is applied is also important. Especially when dealing with very small seeds, watering should be done gently, to avoid disturbing the placement of the seeds or moving media particles onto the growing point of small seedlings. Using a very fine mist nozzle or sprayer or watering from the bottom of the tray are both good options. When bottom watering, do not let the tray remain in water after it is sufficiently moistened, as this can oversaturate the media and greatly reduce oxygen levels.

Germination Temperature

Temperature affects the rate at which seeds germinate. Different species typically germinate over a fairly wide range of temperatures, but germination is usually fastest in a smaller, optimal range. This optimal temperature is what id used for the recommend germination temperature on seed packets. Both low temperatures and overly high temperatures can reduce seed germination, and germination is generally slower at cool temperatures. Most annual flower and vegetable seeds germinate well in a range of 70 to 75°F, though some benefit from cooler or warmer conditions. Providing consistent temperatures in the optimal range generally helps to ensure uniform germination.

Some species germinate best at warmer temperatures, usually 80 to 85°F. Examples include: okra, peppers (particularly *Capsicum chinense, C. baccatum, C. frutescens*), watermelon (especially seedless watermelon varieties, which are best at 90 to 95°F!), muskmelons, and *Rudbeckia fulgida*.

Some species germinate best at cool temperatures, usually 60 to 65°F. Examples include: anemone, delphinium, iberis, Iceland and alpine poppies (*Papaver nudicaule* and *P. alpinum*), lavender, oenothera, pansy, primula, and viola.

Using a thermostatically controlled seedling heat mat is an excellent way to provide the optimal temperature to germinating seeds, particularly for those that prefer warmer temperatures.

Some species germinate best when night temperature is cooler than the day temperature by at least 5 to 10°F. There are a few options for providing alternating temperatures easily. One is to sow directly in the garden or into flats placed outdoors. A second option is to use a timer on a seedling heat mat. Set the timer to turn the heating mat off at night and on again in the morning. This provides cooler temperatures during the night.

Examples of species that benefit from fluctuating temperatures: bloodroot (*Sanguinaria canadensis*), Canadian wild ginger (*Asarum canadensis*), garden phlox (*Phlox paniculata*), iris (*Iris forrestii, I. lactea, I. setosa*), jack-in-the-pulpit (*Arisaema triphyllum* and other *Arisaema* spp.), lady's mantle (*Alchemilla alpina, A. vulgaris*), shrub dogwoods (*Cornus alternifolia, C. amomum, C. alba*), spider flower (*Cleome* spp.), spotted Jewelweed (*Impatiens biflora*), and walnut (*Juglans cinerea, J. nigra*).

Growing On

Once the radicle emerges, growing on temperatures generally should be decreased to 65 to 70°F, and some species prefer even cooler temperatures. Reducing temperature helps to ensure sturdy growth and avoid stretching.

Light Effects

Light can have a stimulating or an inhibiting effect on seed germination for some species. Seed which requires or benefits from light is usually surface sown and not covered. Species requiring dark conditions to germinate are less common than those that benefit from light. Seeds of dark-requiring species are generally planted deeply enough to exclude light from the seed.

Some species have different optimal germination temperatures depending on whether they are exposed to light or kept in darkness.

Understanding Dormancy

Seed Dormancy

Seed dormancy is a condition that allows seeds to survive in the soil in a state of "hibernation" without germinating, often for long periods of time. Some types of seeds can remain in a dormant state for decades or more. This is particularly true of perennials, especially many native perennial species. It is also true for many types of weed seeds. *Verbascum blattaria* and *Malva rotundifolia* have been found to be capable of germinating after *120 years* of dormancy, based on the ongoing seed viability experiment started by Professor W. J. Beal in 1879 at Michigan State University (then called Michigan Agricultural College).

The specific methods that seeds use to remain dormant vary and are not fully understood. Dormancy is beneficial for wild plants, though it is usually undesirable for a gardener. Seed dormancy helps to ensure that a population of plants can survive over time and successfully cope with drought and other stressful conditions. If all the seeds produced by a plant were to germinate at once and weather became unfavorable, all the seedlings could die. Dormancy spreads out germination period, allowing seedlings to begin grow over time (often over several years). This helps to ensure that a population of plants can successfully mature and produce enough seed to keep the population healthy for the long term.

There are a number of different dormancy mechanisms. Dormancy can be caused by physical means (like a seed coat that resists the uptake of water), by physiological means, or by a combination of factors.

Scarification

A common way that seed remains dormant is by having an outer surface that prevents the uptake of water. Scarification is a process used to pierce the seed coat so water absorption can take place. Most seeds with hard, water-resistant seed coats benefit from scarification. Many types of legumes (plants in the bean family, Fabaceae) have hard seed coats, especially when the seed is fully dry. Examples include *Baptisia*, *Lathyrus*, *Lupinus,* and *Thermopsis*. Another family of plants that commonly benefit from scarification is the Malva or hollyhock family (Malvaceae). This family includes *Alcea*, *Hibiscus*, and *Malva* species. Other plants that benefit from scarification include *Langenaria* species gourds (hard shelled gourds) and zonal geranium (*Pelargonium* x *hortorum*).

Seeds that have a somewhat water-resistant seed coat can benefit from soaking in warm water for a few hours or overnight to speed up germination after planting. Examples of seeds that benefit from soaking include: angel's trumpet (*Datura* and *Brugmansia* spp.), asparagus (both edible and ornamental types of *Asparagus* spp.), bells of Ireland (*Moluccella laevis*), blue honeywort (*Cerinthe major*), canna (*Canna* x *generalis*), castor bean (*Ricinus communis*), larkspur (*Consolida* species), okra (*Abelmoschus esculentus*), and St. John's wort (*Hypericum perforatum*).

There are multiple ways to scarify seeds. **Mechanical scarification** is done through physical means. Using a sandpaper to scuff the seed surface is a common technique, and small seeds are often gently rubbed between two sheets of sandpaper to scarify them. Lightly filing or nicking the edge of a seed with nail clippers or a knife can also be done to scarify large seeds. Be careful when doing mechanical scarification, to ensure the seed is not damaged. The goal is to scratch or chip the seed coat just enough to allow it to take up water more easily.

Exposure to **alternating freezing and thawing temperatures** is another way to scarify seed. A common way to naturally expose seed to these conditions is to sow the seed outdoors in fall, either in the ground or in flats. Weather conditions during the winter months will help to naturally break down the seed coat. This is a traditional technique for sowing many perennials, especially native species.

A **hot water treatment** can also be used for seed scarification. Hot (not boiling!) water is used to soak seeds for a few hours to overnight. Be sure that the water is no hotter than 180°F, as higher temperatures can damage seed. An easy way to ensure water is not too hot is to bring water to a boil, remove it from the heat, and allow it to cool for a few minutes before using it to soak seed.

Large commercial growers often use chemical methods to scarify seed. Treating seed with acid is a common technique. This mimics the process that occurs when fruit containing seed is eaten by an animal and seed passes through its digestive system. However, acid requires careful handling, denaturing, and disposal to ensure it is used safely. Overly long treatment can also damage seed.

Stratification

Stratification is done by providing moist conditions and a specific temperature. Cold stratification is the most common technique, and species that need cold stratification are often called "frost germinators."

To cold stratify seed, provide a cool, moist environment (typically 35 to 40°F) for a period of 4 to 12 weeks or longer. Moist conditions are required for successful stratification. Exposing dry seeds to a cold period will not stratify them! (Consider that most bulk seed sold through wholesalers is stored dry at around 40°F.) Often a 2 to 4 period of warm stratification (warm, moist conditions, usually 65 to 80°F) is provided before a cold stratification period.

Seed is often mixed with moistened peat moss, vermiculite, or sand and placed in plastic zipper bags kept in a refrigerator to provide cold stratification. Trays can also be sown in fall in trays and kept in cool conditions or placed directly outdoors to overwinter. This is a very traditional method for sowing perennials and many species of woody plants. One notable German perennial seed supplier still recommends fall sowing and covering trays with snow for perennial species that need stratification.

Species benefitting from stratification include: angel's trumpet (*Datura metel*), bells of Ireland (*Moluccella laevis*), Peruvian lily (*Alstroemeria*), prince's feather (*Polygonum orientale*), solitary clematis (*Clematis integrifolia*), sweet violet (*Viola odorata*), and many species of hardy perennials – especially native perennial species

Winter Sowing

Winter sowing is a technique that is gaining in popularity. It is an outdoor sowing technique commonly used for perennial species, but it can also be used for annuals. It is very similar to outdoor fall sowing, but is done later into the winter season and typically uses covered containers with perforated lids. Recycled food containers like milk jugs or soda bottles are filled with moistened media, sown with seed, and then taped shut and put outdoors where they will be exposed to cold temperatures. Be sure to include a plastic plant tag with the species and variety information, as wooden tags tend to degrade during winter.

When the temperatures warm up in spring, seed will begin to germinate. At this point, remove the lids or add additional ventilation holes, to ensure good air flow and prevent overheating.

Germination Media and Containers

Choosing a Good Media

Garden soil is not a good seed starting mix. When used in containers, it becomes compacted, drains poorly, and does not hold oxygen well. It can also contain weed seeds and pathogens. A good media for starting seeds has a fine-textured particle size, holds moisture well, but also has sufficient pore space to be well aerated. Most seedling mixes are composed primarily of peat moss mixed with perlite (an expanded volcanic rock) and/or vermiculite (an expanded mica). Some mixes now use coir (coconut fiber) instead of or in addition to peat moss. Many also contain compost.

Use a quality, name brand media. Choose a seed starting mix that does not contain a significant amount of fertilizer. High fertilizer levels can lead to high salt levels in the media, which can inhibit germination. Also, it is easy to leach fertilizer out of the mix when watering, and seedlings generally do not need fertilization until after they germinate and the true leaves have expanded.

I am not a fan of gel additives that provide extra water holding capacity to seed starting mixes. These may not break down well in the soil, they hold little water when plants are fertilized, and they usually add significant cost to the media.

Choosing Containers

The optimal container for starting seed can vary, and a wide range of options can be used. Traditionally, full flat, cell-less containers were used and seedlings were "pricked out" and transplanted early into larger containers soon after germination. Transplanting at the proper time, before roots grow too large and become entangled with adjacent seedlings is key when using open flat methods. Using multi-cell trays or flats has become the most common way to start seeds in recent years.

These trays are available in a wide range of configurations and sizes. In general, trays with smaller cells (higher density trays) provide space efficiency, but they can be more challenging to manage culturally, as they need more frequent watering and fertilization. A tray with 50 or 72 cells provides a good balance between space efficiency and easily manageable cultural needs. Commercial wholesale propagators often grow in very high-density trays containing 288 or even 512 cells per tray!

Creative recycling and re-use can turn a wide range of items to seed starting items. Food containers, toilet paper rolls, egg cartons, etc. are often used. Be sure to punch drainage holes in recycled containers, to ensure that they drain properly.

Soil blocks are a container-less option. These can be an excellent choice, but do require an investment in equipment. Standardizing on one size of block will help to reduce equipment expenses. Soil block media is a bit different in composition from standard seed starting media, as it must hold together well. It generally has a much higher proportion of compost than standard peat-based seed starting mixes.

Plantable pots can also be used. These are typically made of paper, peat moss, or composted manure. They are ideal for species that can be difficult to transplant successfully. When using plantable containers, ensure that the top of the container is not above ground. Fold the edge over or tear it off if needed. If the lip is exposed, it can wick moisture from the soil and stress seedlings.

Species that can be difficult to transplant and best started in plantable containers include: beans, corn, butterfly weed (*Asclepias tuberosa*), false indigo (*Baptisia* spp.), okra, oriental poppy (*Papaver orientale*), pea and sweet pea, and vining crops like squash, melon, watermelon, cucumber, gourds, and morning glory.

Bagging and humidity domes

Using a clear plastic humidity dome over trays can help to increase humidity levels during germination and reduce water needs. Domes that have a vent are ideal, as they maintain humidity and still allow for some aeration. Domes without a vent can be propped up slightly so there is a ¼ to ½ inch gap on one side of the tray. Clear plastic bags can be used instead of domes.

When bagging or using domes, increase the amount of ventilation as the seedlings grow, to ensure that they are receiving sufficient oxygen. Avoid bagging and using domes when growing seedlings in a greenhouse or other location that receives strong direct sunlight, to avoid overheating. Also note that these covers, though they are transparent, will reduce light levels.

Scheduling

Container size has an influence on the time that a seedling can be grown before it needs to be transplanted. In 3 inch or larger pots, seedlings can generally be grown until they are ready to be transplanted to the garden. In smaller containers, seedlings will need to be transplanted to a larger size cell or container before they become root bound. A good rule of thumb for the proper transplant time is to transplant when the seedlings develop their second set of true leaves.

Allowing seedlings to become rootbound will stress the plants, slow growth, and can reduce yield. An important goal is to ensure that seedlings are not stressed at any time during their growth.

Labeling

It is always helpful to use a label with the specific variety and type of plant being started from seed, plus a backup “map” on paper. This helps to ensure you don’t mix up varieties or lose track of what varieties are being grown in case plant tags are lost.

Dealing with Diseases

Gardeners often struggle with "damping off" diseases affecting their seedlings. Damping off is caused by a fairly wide range of species of disease organisms, including *Fusarium, Pythium*, *Phytophthora*, and *Rhizoctonia*. These are common microbes responsible for a range of diseases.

The most effective way to manage these diseases is through proper moisture management! The vast majority of problems with disease in seedlings is due to keeping the media overly wet. Damping off is most commonly more of a cultural problem than a disease problem.

The **disease triangle** concept explains this phenomenon. For disease infection to occur, there are 3 factors that must be met. First, a pathogen must be present; second, a susceptible host must be present; and third, there must be a favorable environment for infection. If any factor is lacking, disease infection cannot occur. Without an overly wet soil, a favorable environment for infection is usually lacking, and damping off disease is unlikely to occur.

Treating reused trays and containers

When re-using trays and other containers to grow seedlings, you can sterilize them with a dilute bleach solution to reduce potential problems with diseases. First, scrub the containers to remove all media and residues. Particles of media and other residues remaining in containers will reduce the effectiveness of the sterilization. Use a 10% (volume to volume) solution of household bleach (sodium hypochlorite) to water. This is 1 part bleach to 9 parts water. Example: ¼ cup bleach, 2 ¼ cups water. Soak for 10 minutes, then rinse well with plain water. Wear rubber gloves when working with bleach solution.

Bleach Treatment

A 10% solution (by volume) of household bleach can also be used as a seed soak to sterilize the seed coat. Seed is soaked in the bleach solution for about a minute, rinsed with plain water for 3 to 5 minutes, and then spread on newspaper or paper towels to dry.

Hot Water Treatments

In addition to being used as noted previously for scarification, hot water treatments can also be used to control seed-borne pathogens, but the need to control the temperature exactly makes this method difficult to use on a hobby level. Precision controlled water bath equipment is generally needed for exact control of temperature when heating seed. Typically 122°F is used for 10 to 30 minutes, but a few species require longer times and a bit higher temperatures. The need for exact temperature control for the entire heating time is to ensure the treatment is effective and does not damage seeds. Note that most cucurbits (squash, melons, gourds, and pumpkins) should not be hot water treated, as they are too easily damaged.

Peroxide Treatment

Consumer grade hydrogen can also be used without dilution to surface sterilize seeds. A 1 to 2 minute soak is generally sufficient.

Beneficial microbes & compost extracts

Compost extracts increasingly being studied as a way to reduce diseases (including seed borne diseases, both fungal and bacterial). This effect can be due to inhibitory compounds produced by microbes in compost, by competition from beneficial microbes, by predation of disease organisms by beneficial microbes, or a combinations of the three. Compost extracts are generally made by soaking 1 part compost in 2 parts water for a few hours, then straining the solution.

Aerated compost teas are similar to compost extracts, but are "brewed" for a longer period (generally 24 to 36 hours) and include microbial food like molasses or fish emulsion. Active aeration ensures that microbial growth is rapid. Usually 2 cups of compost per 5 gallons of water are used.

Both types of compost extracts can be used at full strength or diluted before application.

Commercial Microbial Products

There are an increasing number of commercial microbial products available that can be used to treat seeds and seedlings to reduce disease problems. Some are used as a foliar spray, others can be used on the soil or on leaves. These products contain beneficial microbes that colonize plant surfaces and make them resistant to infection by disease organisms. An example of a commercial product that can be used as a foliar spray, seed treatment, or soil drench is Actinovate, which contains *Streptomyces lydicus* bacteria.

Treatments to Improve Germination

Smoke Treatment

Fire is a germination stimulant for some species of plants, particularly woody plant species native to fire prone areas in South Africa, Australia, and the Western US. Research also indicates that for some plants chemicals in smoke that stimulate germination. A compound called butenolide in smoke is thought to be involved in this effect. Exposure to smoke can result in improved germination, including faster germination rate and improved seedling vigor in some species. This is still experimental, and more research is needed to fully understand how best to use smoke treatments to improve germination.

If you wish to try smoke treatment at home, start with a 1% liquid smoke solution and soak seed 6 to 24 hours before sowing. Use an "all-natural" liquid smoke, like Wright's. To make a gallon of smoke solution very close to 1% concentration, add 3 tablespoons of liquid smoke to a gallon of water.

Plants that benefit from smoke treatment include: American feverfew (*Parthenium integrifolium*), Canadian milk vetch (*Astragalus canadensis*), coneflower (*Echinacea pallida, E. purpurea, E. paradoxa),* corn (*Zea mays*), gayfeather (*Liatris spicata*), mountain mint (*Pycnanthemum pilosum, P. virginianum*), New Jersey tea (*Ceanothus americanus*), pumpkin (*Cucurbita pepo*), round-headed bush clover (*Lespedeza capitata*), sideoats grama (*Bouteloua curtipendula*), stiff goldenrod (*Oligoneuron rigidum* var. *rigidum*), Tennessee purple coneflower (*Echinacea tennesseensis)*, and tickseed coreopsis (*Coreopsis lanceolata*).

Hydrogen Peroxide

A 10 to 20 minute soak in full concentration consumer grade hydrogen peroxide can help to break down hard seed coats and will also sterilize the seed coat.

Worm Castings (Vermicompost)

Worm castings contain small amounts of the plant hormone gibberelic acid (GA), which can promote germination in many species. You can top dress seed lightly with castings after sowing, include 5 to 10% worm castings in the seed starting mix (by volume), or use a worm casting "tea" to water in seeds.

Bleach

Some species, notably many wild tomato species (*Solanum cheesmaniae*, *S. galapagense*, *S peruvianum* and others) benefit from treatment with a bleach solution to improve germination. A fairly long bleach soak weakens the seed coat in these species. Seed is soaked for 30 to 60 minutes in a 1:1 mixture of water and household bleach, rinsed, and sown without being allowed to dry. This method can also be used to treat old seed lots of tomato that have not been stored at optimal temperatures.

Fresh Germinators

Germination requirements can change over time. In some cases, a period of dry storage can result in improved germination. In other cases, species become dormant with storage. In a few cases, fresh seed will germinate readily, and seed dies rapidly in storage, typically having a shelf life of 6 months or less, even when stored under ideal conditions. I call this type of plant a "fresh germinator." They are best sown as soon as possible after harvest, and the best success may come from harvesting seed from your own "mother plants." For some species, cold stratification may be helpful when working with seed of fresh germinating species which has been stored, but this is not always effective.

Examples of fresh germinators include: false anemone (*Anemonopsis*), hellebore (*Helleborus*), masterwort (*Astrantia*), monkshood (*Aconitum*), and spring adonis (*Adonis vernalis*).

Dealing With Very Old Seeds

There are a few techniques that have proven effective when trying to germinate very old seed, particularly if it was stored in sub-optimal conditions. These work well with seeds of tomato, pepper, and eggplant that are 10 or more years old.

Mix up a dilute solution of any good, balanced liquid fertilizer. Mix at about one-third strength (1 teaspoon per gallon of water if the usual rate is 1 tablespoon per gallon.) Moisten, but do not fully saturate a paper towel or two with the fertilizer solution. Place seed to be germinated on the paper towel so that it is not clumped together. Seeds that are touching are likely to rot. Fold the paper towel over the seed and place the seed in a zipper storage bag. Seal the bag so that it contains air, and place in a refrigerator for 16 to 20 hours. Before removing seed, prepare a germination tray with a high quality growing medium and moisten it properly. Remove the bagged seed from the refrigerator and carefully sow each seed on the surface of a container filled with seed starting medium. Cover the seed only very lightly with bit of growing medium or with coarse vermiculite. Ensure the covering is minimal enough so the seeds will still receive some light. Germinate at 85°F, using a heat mat or other system to ensure the media remains consistently at the proper temperature. Check daily for germination for 3 weeks.

A bleach or hydrogen peroxide surface sterilization before placing seeds in paper towels may be helpful, particularly if the seed is known to be prone to disease.

For More Information

Handouts from Allen's other talks on seed propagation can be found at the PerennialGuru Seed Propagation Page - http://www.perennialguru.com/WP/?page_id=42

PanAmerican Seed produces an excellent Seed Product Information Guide (their "PIG") available as a free .pdf - https://www.panamseed.com/catalogs.aspx

Dr. Norman C. Deno (a retired chemistry professor) did a lot of work after retirement classifying plant germination requirements, and he produced a book plus two supplements with his findings. Dr. Deno is no longer conducting this research and his books are out of print, but they available for download through the National Agricultural Library Digital Collections (NALDC).

- *Seed Germination, Theory, and Practice* - http://naldc.nal.usda.gov/catalog/41278
- First supplement - http://naldc.nal.usda.gov/catalog/41279
- Second supplement - http://naldc.nal.usda.gov/catalog/41277

Dr. Deno's books include information on using Gibberelic Acid (GA) to overcome dormancy. GA can be ordered from JL Hudson Seedsman - http://www.jlhudsonseeds.net/GibberellicAcid.htm

The USDA's *Woody Plant Seed Manual* (Agriculture Handbook 727) is available as a free .pdf download. This is a very extensive (over 1,200 pages!) and thorough reference for germination of numerous tree and shrub species - http://www.rngr.net/publications/wpsm