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introduction to organic vegetables

Seed and Seedling Biology

As organic producers, we try to mimic nature in order to grow food with a minimum of external inputs. If we plan to mimic nature, we need to understand as much about the biology of plants and ecological systems as we can. The following introduction may be a review for some, but it will hopefully give new producers an understanding of seed and seedling biology and a framework for analyzing cultural practices for producing healthy seedlings.

CHOOSING THE RIGHT SEED

Before exploring how to best grow your seeds and seedlings, start with the right seed. If you intend to run your operation as certified organic, you are required to use certified organic seed and seedlings with only a few exceptions (see the “Organic Requirements for Seeds, Planting Stock, and Seedlings” sidebar on p. 6).

WHAT DO SEEDS NEED TO GERMINATE?

Viable seeds are living entities. They must contain living, healthy embryonic tissue in order to germinate. All fully developed seeds contain an embryo and, in

most plant species, a store of food reserves, wrapped in a seed coat. Seeds generally “wake up” and germinate when soil moisture and temperature conditions are correct for them to grow (Miles and Brown 2007). Each seed type has individual needs—take a minute and read about their specific germination requirements.

Seeds Need the Right Environment to Germinate

Temperature, moisture, air, and light conditions must be correct for seeds to germinate. All seeds have optimal temperature ranges for germination (Table 1). The minimum temperature is the lowest temperature at which seeds can germinate effectively. The maximum is the highest temperature at which seeds can germinate. Anything above or below this temperature can damage seeds or make them go into dormancy. At optimal temperatures, germination is rapid and uniform.

All seeds need correct moisture to initiate internal processes leading up to germination. In field soil this is generally about 50–75 percent of field capacity. A fine-textured seedbed and good seed-to-soil contact are necessary for optimal germination. Aeration in the soil media allows for good gas exchange between the germinating embryo and the soil. Seeds respire just like any other living organism. They need oxygen and produce carbon dioxide (CO₂). This carbon dioxide

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TABLE 1. SOIL TEMPERATURE CONDITIONS FOR VEGETABLE CROP GERMINATION.

	Minimum (°F)	Optimum Range (°F)	Optimum (°F)	Maximum (°F)
Beet	40	50–85	85	85
Cabbage	40	45–95	85	100
Cauliflower	40	45–85	80	100
Celery	40	60–70	70	85
Chard	40	50–85	85	95
Cucumber	60	60–95	95	105
Eggplant	60	75–90	85	95
Lettuce	35	40–80	75	85
Melons	60	75–95	90	100
Onion	35	50–95	75	95
Parsley	40	50–85	75	90
Pepper	60	65–95	85	95
Pumpkin	60	70–90	90	100
Spinach	35	45–75	70	85
Squash	60	70–95	95	100
Tomato	50	70–95	85	95

Soil temperatures should be taken by inserting a soil thermometer 3–4 inches deep into the soil surface and noting temperature. Adapted from Kemble and Musgrove (2006).

needs to be able to move away from the seed. If the soil or media is not well aerated due to overwatering or compaction, the CO₂ will not dissipate and seeds can suffocate.

Not all seeds have the same light requirements. Most seeds germinate best under dark conditions and might even be inhibited by light (e.g., *Phacelia* and *Allium* spp.). However, some species (e.g., *Begonia*, *Primula*, *Coleus*) need light to germinate (Miles and Brown 2007). Don't confuse seed light requirements with what seedlings need. All seedlings require sunlight. Seedlings will become leggy and fragile and will not produce to their potential if they do not have sufficient light.

SEED DORMANCY

Some viable seeds might not germinate. Many seeds have developed a dormancy (or sleep) period. Seed dormancy is a condition that prevents germination even under optimal environmental conditions. Why would it benefit seeds to not all germinate when conditions are right? In nature, staggering germination keeps some seedlings safe from possible bursts of bad weather or herbivores that might eat them. Seeds of plants that grow best in the spring have self-selected to germinate only after cold winter temperatures have passed.



Seedlings will become leggy and weak in low light situations.

For seeds to come out of dormancy, we have to break their physical or chemical dormancy factors. Seeds might have a hard or thick seed coat (physical dormancy). This can be broken by soaking or scarifying (scratching the surface) the seed. Other seeds have internal chemical or metabolic conditions that prevent germination (chemical dormancy). Factors affecting seed dormancy include the presence of certain plant hormones—notably, abscisic acid, which inhibits germination, and gibberellin, which ends seed dormancy. To break chemical dormancy, you might have to leach the seed or use cold/moist stratification or fire scarification. For example, the membrane within the seed coat of some seeds forms a barrier that is permeable to water but not to oxygen. Cold temperatures (50–59°F) allow oxygen to get into the seed, while warm temperatures prevent oxygen uptake. Cool temperatures also allow the seed to digest some of its food reserve, giving it energy. For these seeds, putting them in the refrigerator for a specific period of time allows them to gain sufficient oxygen and energy to germinate (Colorado Seed Laboratory 2009).

STEPS OF SEED GERMINATION

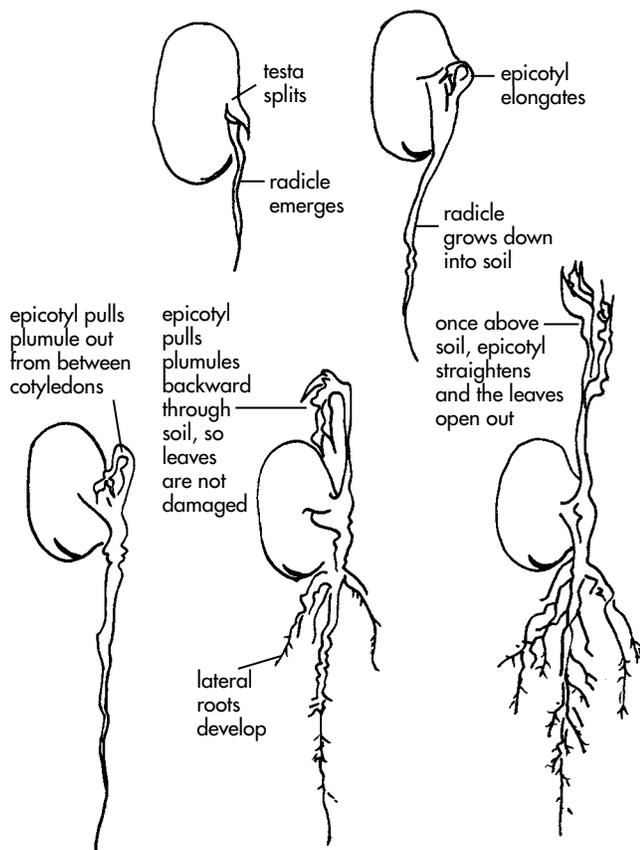
1. **Imbibition.** The seed rapidly takes up water and the seed coat swells and softens. Think of a pea seed that you have soaked—the outer seed coat becomes soft and wrinkly with water.
2. **Interim or lag phase.** During this phase the seed activates its internal physiology, cells respire, and the seed starts to make proteins and metabolize its stores of food (MacKean n.d.).
3. **Radicle and root emergence.** The cells start to elongate and divide, bringing the root and radicle out of the seed.



To find out whether or not your seed is viable, do a germination test. Wrap seeds in a moist paper towel, wait 5–10 days, and count how many seeds germinate.

If you save your seed from the year before, think about this: the life of a seed can be cut in half by an increase of just 1 percent in seed moisture or by an increase in storage temperature of just a few degrees. A simple rule of thumb is that the sum of the storage temperature (in degrees Fahrenheit) and percent relative humidity should not be greater than 100.

ILLUSTRATION 1: STEPS OF SEED GERMINATION.



EARLY SEEDLING DEVELOPMENT

Dicots (Two-seed Leaves)

The primary root, called the radicle, is the first thing to emerge from the seed. The primary root anchors the plant to the ground and allows it to start absorbing water. After the root absorbs water, the shoot emerges from the seed. In dicots, the shoot has three main parts: the cotyledons (seed leaves), the section of shoot below the cotyledons (hypocotyl), and the section of shoot above the cotyledons (epicotyl). The way the shoot emerges from soil or growing media follows two main patterns. In some plants, the section of the shoot below the cotyledons elongates and forms a hook, pulling the cotyledons and the growing tip through the soil. Once it reaches the surface, it straightens and pulls the cotyledons and shoot tip of the growing seedlings into the air. For example, beans germinate this way. This is called epigeous germination. In other plants, only the section above the cotyledons expands, leaving the cotyledons underground where they soon decompose. This is called hypogeous germination. Peas, for example, germinate this way (Raven, Ray, and Eichhorn 2005).

Monocots (One-seed Leaves)

In monocot seeds, the primary root is protected by a sheath (coleorhiza), which pushes its way out of the seed first. Then the seedling leaves emerge covered in a protective sheath called a coleoptile (Raven, Ray, and Eichhorn 2005).

Dicots and Monocots

After the shoot emerges, the seedling grows slowly while the storage tissue of the seed diminishes. Soon, the plant develops a branched root system or taproot. Then, true leaves that look like the leaves of the mature plant appear. These leaves, unlike cotyledons, photosynthesize light into energy, allowing the plant to grow and develop.

MANAGING FOR OPTIMAL GERMINATION AND SEEDLING DEVELOPMENT

Optimizing Germination

We know that seeds need optimal amounts of water, oxygen, temperature, and light to germinate. If we don't create the most optimal environment possible, then plants tend to germinate slowly and unevenly. Generally, greenhouse space is limited, so we want plants to germinate as quickly as possible. Uneven germination can also cause problems. If you have ever had to transplant out a flat of seedlings where half are ready to plant and the other half are too small with root balls that don't slide easily out of their cells, you will understand why.

TABLE 2. TEMPERATURE AND TIME REQUIRED FOR GROWING FIELD TRANSPLANTS.

	Day (°F)	Night (°F)	Time (weeks)
Broccoli	60–70	50–60	5–7
Cabbage	60–70	50–60	5–7
Cauliflower	60–70	50–60	5–7
Celery	65–75	60–65	10–12
Cucumber	70–75	60–65	3–4
Eggplant	70–80	65–70	6–8
Lettuce	55–65	50–55	5–7
Melons	70–80	65–70	3–4
Onion	60–65	55–60	10–12
Pepper	65–75	60–65	6–8
Squash	70–75	60–65	3–4
Tomato	65–75	60–65	5–7

From Maynard and Hochmuth (2007).



Heat stress can cause severe damage to tiny seedlings. These recently emerged broccoli seedlings were exposed to temperatures of 118°F.

One common option to achieve optimal germination temperature in growing media is to use germination mats. These mats allow you to set the temperature according to seed requirements. For example, peppers will germinate in 8 days at 86°F, but take more than 13 days to germinate at 58°F (Pennsylvania Heirloom Seed Savers Club n.d.).

Make sure you maintain optimal temperatures for your crop (see Table 1 above). It is also critical to promote air circulation to mitigate fungal pathogens such as those causing damping off.

Seedling Development

The optimal temperature for growing seedlings may be different from that for seeds (Table 2). Remember, optimal temperature will stimulate optimal growth. You can control temperature to control plant height. Cooler temperatures generally slow down growth, and warmer ones speed up growth.



Shallow watering will leave most of the roots dry and stress the plant. See the lighter colored potting mix in the bottom half of the root ball (left).



Poor onion germination due to over watering, cold soils, and damping off complex.

It is still critical to maintain good air circulation and sufficient moisture. Generally, watering should be deeper to accommodate developing root systems. You may need to use different wand or hose heads to water seeds and seedlings because each use different amounts of water. Remember to carefully monitor and water the plants at the edges of flats. They dry out faster than those in the middle. However, overwatering can increase the probability of plants developing damping off.

Seedling Maturation and Hardening Off

This final step before seedlings are planted in the field gradually exposes them to the conditions they will have in the field. This process stimulates the plants to accumulate carbohydrate and nutrient reserves and strong cell walls by exposing the plants to day and night temperature fluctuations, increased air movement and wind, reduced watering, and full light.

Hardening off transplants is important, especially if they are to be planted under stressful early season conditions. Most transplants may be hardened off by reducing the temperature in the greenhouse through ventilation. Reduced watering will also provide some hardening effect. Do not let plants wilt excessively. Do not harden off transplants by reducing fertilizer application, as this often results in stunted plants that do not establish well in the field. Some growers will put plants outside for 5–7 days prior to planting. This allows the plant to become acclimated to outside conditions while still in the flat. Plants hardened off in this manner often have improved field performance as compared to those planted directly from the greenhouse (Garton, Sikkema, Tomecek 1997).

ORGANIC SEED SOURCES

Listed below are a number of sources for organic seed provided by Pennsylvania Certified Organic (2011). A list is also maintained by the Organic Materials Review Institute (OMRI) at omri.org. For a more complete listing including forage, field crop, and cover crop seed and transplants, go to paorganic.org.

Abundant Life Seeds

PO Box 157
Saginaw, OR 97472
Phone: 541-767-9606
Web: www.abundantlifeseeds.com
E-mail: info@abundantlifeseeds.com
100 percent organic, all open-pollinated; vegetable, flower, and herb seed; garlic and potatoes

The Cook's Garden

PO Box C5030
Warminster, PA 18974
Phone: 800-457-9703
Web: www.cooksgarden.com
E-mail: cooksgarden@earthlink.net
Organic vegetables, beans, flowers, and herbs

Environmental Seed Producers

PO Box 947
Albany, OR 97321-0354
Phone: 541-928-5868
Web: www.espseeds.com
Organic vegetables, herbs, and flowers

Fedco Seeds

PO Box 520
Waterville, ME 04903
Phone: 207-873-7333
Web: www.fedcoseeds.com
Organic vegetables and flowers

Filaree Farm

182 Conconully Hwy
Okanogan, WA 98840
Phone: 509-422-6940
Web: www.filareefarm.com
Extensive collection of organic garlic varieties

Fred C. Gloeckner and Co.

600 Mamaroneck Avenue
Harrison, NY 10528-1631
Phone: 800-345-3787
Fax: 914-698-2857
Web: www.fredgloeckner.com
Organic vegetable, herb, and flower seeds

Gardens Alive!

500 Schenley Place
Lawrenceburg, IN 47025
Phone: 513-354-1482
Web: www.gardensalive.com
Organic garden and sprout seeds, plus insect and disease control and soil care products

Harris Seeds

355 Paul Road
PO Box 24966
Rochester, NY 14624-0966
Phone: 800-544-7938
Web: www.harriseseeds.com
Some organic vegetables and herbs

High Mowing Organic Seeds

76 Quarry Road
Wolcott, VT 05680
Phone: 802-472-6174
Web: www.highmowingseeds.com
High-quality organic seed for more than 500 varieties of heirloom, open-pollinated, and hybrid vegetables, flowers, herbs, potatoes, garlic, and cover crops

Johnny's Selected Seeds

955 Benton Avenue
Winslow, ME 04901
Phone: 877-JOHNYS (877-564-6697)
Web: www.johnnyseeds.com
Organic vegetables, flowers, and herbs

The Maine Potato Lady

PO Box 65
Guilford, ME 04443
Phone: 207-343-2270
Web: www.mainepotatolady.com
Organic seed potatoes, shallots, onion sets, garlic, and cover crops, plus fertilizer, soil, and seed inoculants

Organic Requirements for Seeds, Planting Stock, and Seedlings

The National Organic Standards require that producers use organically grown seeds, annual seedlings, and planting stock. Nonorganically produced, untreated seeds and planting stock may be used to produce an organic crop when an equivalent organically produced variety is not commercially available.

There is no allowance for seed treated with prohibited materials. Captan, thimet, and similar chemical fungicides are not on the national list and are not permitted. Please take this seriously. If your seed is covered in a pink or orange powder, it is probably prohibited. We may not be able to certify your crop if you use seed treated with prohibited materials.

Seeds used for edible sprout production must be organic—no exceptions.

Commercial Availability

The first step is to determine whether an equivalent organically produced variety is available. By equivalent variety, look for comparable growing habits, days to maturity, insect and disease resistance, flavor, and other important qualities. If a suitable organic equivalent variety is not available, document where you tried to look for organic seed, as that is important for your certification records. Once you have found a source for a specific equivalent organic seed, the next step in determining commercial availability is to see if it is of the appropriate form, quality, and quantity.

- **Form:** such as sized, graded, pelleted, hot water treated
- **Quality:** try a small quantity the first year to make sure it does well under your particular conditions; if the only organic seed available is of inferior quality, then buying nonorganic may be acceptable
- **Quantity:** for example, if you want to plant 1 acre of pumpkins and the only organic seed available is in 1-ounce packets, then buying nonorganic may be acceptable

Documentation and Good Faith Efforts

Prior approval by Pennsylvania Certified Organic for using nonorganic seeds/planting stock is not required. Compliance is reviewed in the context of the organic system plan, which is verified during the annual inspection. A pattern of inadequate documentation and lack of good faith effort to obtain organically grown seeds and planting stock may be considered noncompliance and might result in Pennsylvania Certified Organic requiring prior approval regarding commercial availability issues in future planting cycles. Documenting your good faith efforts to find suitable organic seeds/planting stock is crucial.

Rohrer Seeds

PO Box 250
Smoketown, PA 17576
Phone: 717-299-2571
Web: www.rohrerseeds.com
Organic vegetable seeds

Seeds of Change

3209 Richards Lane
Santa Fe, NM 87507
Phone: 888-762-7333
Web: www.seedsofchange.com
Organic flowers, herbs, vegetables, and cover crops and strawberry plants

Seed Savers Exchange

3094 North Winn Road
Decorah, IA 52101
Phone: 563-382-5990
Web: www.seedsavers.org
Some organic vegetables, garlic, herbs, potatoes, and heirloom varieties

Seedway

99 Industrial Road
Elizabethtown, PA 17022
Phone: 800-952-7333
Web: www.seedway.com
Some organic vegetables and herbs

Snow Seed Organic

21855 Rosehart Way
Salinas, CA 93908
Phone: 831-758-9869
Web: www.snowseedco.com
Many organic vegetables, including lettuces

Southern Exposure Seed Exchange

PO Box 460
Mineral, VA 23117
Phone: 540-894-9480
Web: www.southernexposure.com
More than 400 varieties of certified organic heirloom and open-pollinated vegetable, herb, and flower seeds, as well as garlic and perennial onion bulbs

Territorial Seed Company

PO Box 158
Cottage Grove, OR 97424
Phone: 800-626-0866
Web: www.territorialseed.com
Organic flowers, herbs, vegetables, garlic, and cover crop seeds, plus OMRI-listed fertilizers and soil amendments

Vitalis Organic Seeds

7 Harris Place
Salinas, CA 93901
Phone: 831-262-7635
Web: www.vitalisorganic.com
Organic vegetable and herb seeds, with emphasis on lettuce, spinach, tomato, pepper, cucumber, squash, and melons

Wood Prairie Farm

49 Kinney Road
Bridgewater, ME 04735
Phone: 800-829-9765
Web: www.woodprairie.com
Organic garden seed, seed potatoes, and cover crop seed

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