Germination and Seedling Development

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In the process of producing a crop, getting a good stand and uniform plant population is a critical step and sometimes one of the most challenging. That is particularly true with crops that require expensive seed and there are tight production schedules. A review of the fundamental stages of seed germination and seedling development can be helpful in early season field evaluations.

Seeds are living organisms, and they need healthy embryonic tissue to germinate. Most plant species have food reserves to carry the seedling through germination and emergence. The embryo and food reserves are covered in a seed coat and the seeds are stimulated, or they "wake up", in response to an appropriate range of moisture, temperature, and light conditions that serve to initiate the germination process (Moore et al., 1998).

There are three distinct steps in the process of seed germination.

1) **Imbibition**. Water from the soil moves into the seed, the seed coat softens and swells.
2) **Interim or lag phase**. In this part of germination, the internal seed physiology is activated, and cells begin to respire, and the seed begins to build proteins and metabolize its stores of food.
3) **Radicle and root emergence**. The cells in root tissue start to elongate and divide and this begins pushing the radicle, the embryonic root, out of the seed.

Lettuce plants experience thermodormancy, which is a state of dormancy induced by high temperatures that prevents germination. This is an adaptive trait that is common with some cool-season plants. This prevents seeds from sprouting during the hot conditions that can create plant stress and poor-quality growth (Gardner et al., 1985 and Maynard and Hochmuth, 2007).

A range of optimum temperatures for a select group of common vegetable crops is shown in Table 1. Note that lettuce has an optimum temperature range for germination of 40-80 ºF with an optimum temperature of 75 ºF and a maximum temperature of 85 ºF.

Lettuce is a cool-season plant, and these are common temperature ranges for germination, but the soil temperature conditions commonly experienced in the low deserts in August, September, and October when thousands of acres of lettuce are being planted and established, commonly exceed these lettuce temperature ranges for germination.

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	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

Table 1. Crop germination temperature ranges for a select set of vegetable crops. Source: Kemble and Musgrove, 2006.

The temperature limits for lettuce have been modified to some extent by plant breeding and improvement programs that have produced lettuce varieties that can better accommodate hot conditions. However, there are limits to the genetic elasticity in this regard and we are not changing a cool-season plant to a warm-season plant. To further accommodate these natural temperature limits with a plant like lettuce, sprinkler irrigation systems are used to both moisten and cool soil temperatures to a range that encourages lettuce seed germination and emergence (Figure 1).

Figure 1. Sprinkler irrigation on recently planted lettuce field, Yuma Valley, Arizona.

The first step in germination is water entering the plant (imbibing) water from the soil. In dry lettuce seeds for example, this is primarily a physical process driven by the high-water potential gradient between the dry seed and the surrounding moist soil medium. For many seeds, including lettuce, a key entry point for water is the micropyle, which is a small pore or opening in the seed coat. In many species, water enters through the micropylar end, which is where the radicle (embryonic root) will later emerge.

The first thing to emerge from the seed is the primary root, called the radicle, which we often refer to as the "stinger" (Figure 2). The primary root serves to both anchor the plant to the ground and it also begins to absorb water. After enough water is absorbed into the seed, the shoot emerges. In dicot plants (most broadleaf plants), the shoot has three main parts: the cotyledons (seed leaves), the hypocotyl, the section of shoot below the cotyledons, and the epicotyl, the section of shoot above the cotyledons (DuPont, 2025).

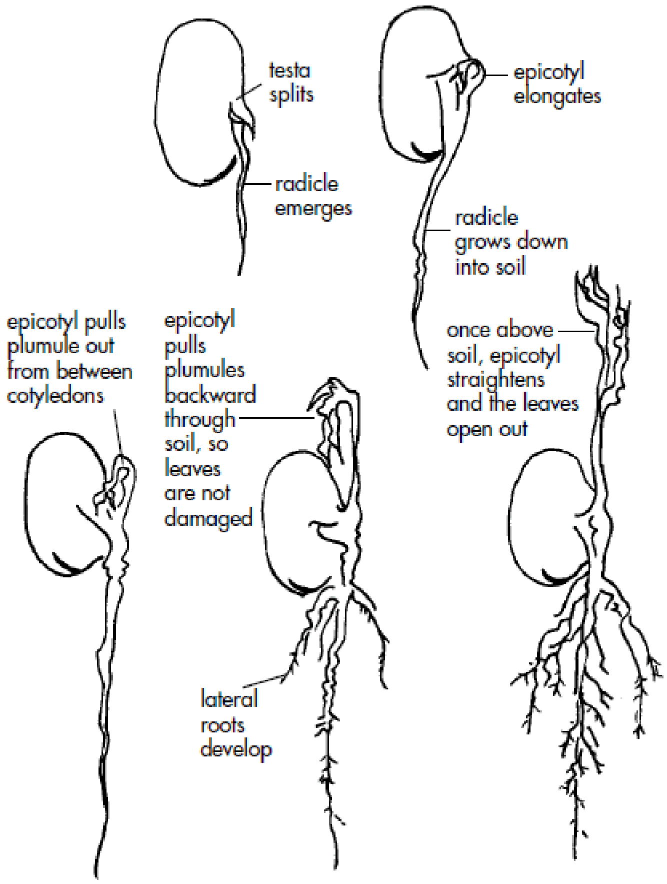

Figure 2. Germination stages for lettuce and other dicotyledonous crops. Source: Seeds and Seedling Biology, Penn. State University, 2025.

These early stages of germination and emergence shown in Figure 2 are critical in establishing a healthy plant, a strong stand, and a good plant population. Root development includes an elongation of the radical and the formation of lateral and secondary roots. The epicotyl will be elongating simultaneously and proceeds towards soil emergence. Early root development is very important part of this process and a good reason to manage soils for good physical condition.

There are two basic patterns of germination and plant shoot emergence. One is “epigeous” germination, where a section of the shoot below the cotyledons elongates and forms a hook. The hooks will pull the cotyledons (seed leaves) and growing point (apical meristem) up through the soil and above the surface. After reaching the soil surface, the hook will straighten and pull the cotyledons and growing point upright into the air. Most dicot plants germinate in this manner. For example, lettuce plants and beans germinate this way (Figure 3).

The other form of plant germination is “hypogeous” development. In this case, the section above the cotyledons expands, leaving the cotyledons underground where they soon decompose. This is called hypogeous germination. Most monocot plants emerge this way, but some dicot plants have this form of germination. Some examples of crop plants with hypogeous emergence include peas, lentils, maize (corn), and rice (Knee, 2024). Cereal grain crops have hypogeal emergence.

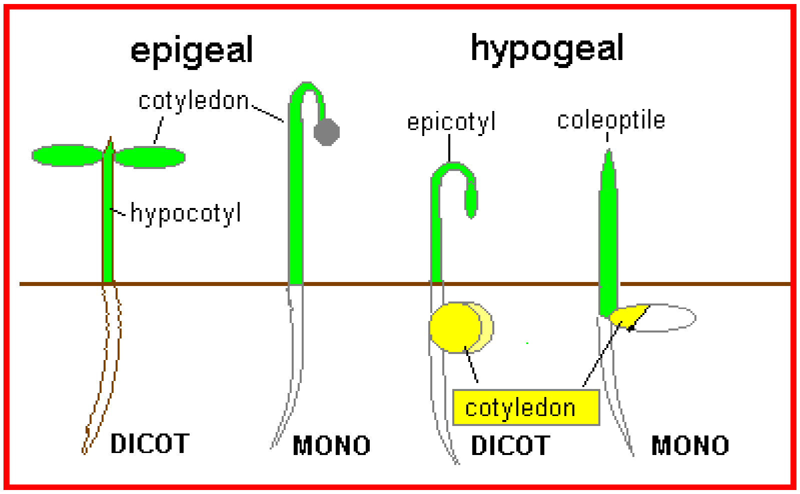

Figure 3. Epigeal and hypogeal emergence. Source: Michael Knee, The Ohio State University.

Further illustrations of emergent lettuce plants are shown in Figures 4 and 5.

During the emergence process when a dicot plant is in the "hook" stage, it is a critical time when the hook is trying to push through the soil surface. Plant species with small seeds are commonly not very strong with this process and that can be exacerbated with any soil crusting. This is another reason sprinkler irrigation is often used to diminish soil crusting and facilitate germination and emergence in the low desert vegetable crop production regions (Figure 1).

Figure 4. Cotyledons. Source: Spider Farmer.

Figure 5. Emergent stages of seedlings. Source: Spider Farmer.

Planting cool season crops, i.e., leafy green vegetables, in the lower Colorado River Valley in August, September, and October is a challenging operation. It is good to keep in mind the fundamentals of seedling germination and early development in field evaluations. These are critical stages of growth that have lasting impact on the vigor and health of the crop.

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