Agronomic Spotlight

Seminis
grow forward

Vegetable Seed Germination and Emergence

- High seed germination percentages and uniform germination rates result in uniform plant stands that help maximize production of vegetable crops.
- Germination and emergence are affected by seed quality and environmental conditions.
- Managing temperature, moisture, and seedbed texture help promote good germination and emergence.

The Germination Process

Plant seeds are made up of an embryo, some form of food storage, and a seed coat. The embryo is the part of the seed that will develop into the root, stem, and shoot of the new plant.[1] Seeds remain in a dormant state until the internal and external conditions allow the seed to break dormancy and initiate the process of germination. The external conditions that influence dormancy and germination include temperature, moisture, air, and light (for some species).

The process of germination is divided into three phases. Phase one is imbibition, when water is imbibed through the seed coat, causing the seed to expand and the seed coat to crack.[1,2] Phase two is the interim or lag phase. This phase involves the hydration of the cotyledons and the activation of the embryo's internal mechanisms of physiology and metabolism. The seed starts using its stored food in this phase.[2,3] The third phase is the growth phase, when the radicle emerges from the seed and begins to develop into the root (Figure 1).[1,2] As the root develops, it anchors the plant and begins to absorb water and nutrients from the surrounding substrate (soil or planting mix). The hypocotyl starts to expand, moving the seed from germination to emergence.

Figure 1. Structures that develop during seed germination.

Once the cotyledons emerge from the soil, the plant has entered the seedling stage. Vegetable crops are classified as monocotyledonous (monocots) or dicotyledonous (dicots), based on the number of cotyledons (seed leaves) they produce. Dicots produce two cotyledons and include crops

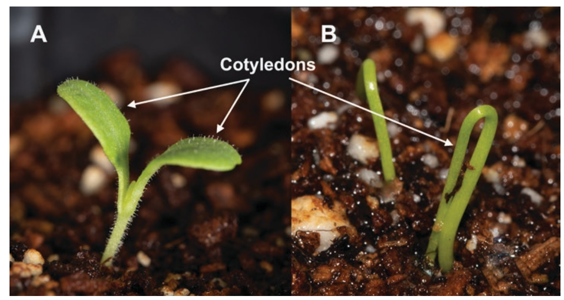

Figure 2. (A) dicotyledonous and (B) monocotyledonous seedlings.

such as tomatoes, peppers, brassicas, cucurbits, beans, beets, and lettuce. Monocots produce one cotyledon and include crops such as sweet corn, onions, and asparagus (Figure 2).[1]

Some plants, such as beans, use their cotyledons to store food, which is used during germination and emergence until the true leaves form. Other plants, such as broccoli or corn, use their cotyledons to make food via photosynthesis.[1] Once seedlings emerge, true leaves start to form and take over the role of food production.

Seed Quality

Seed quality ratings are based on the percentage of seeds that germinate and the rate of germination, usually defined as the number of days from planting to 50% of the seeds germinated. Both the percent and rate of germination are affected by temperature and moisture conditions, so seed quality tests are usually conducted under ideal conditions for germination.[2,4] Evaluation of germination under field conditions is also helpful, as some seed that perform well in seed quality tests may not germinate and emerge well under more adverse field conditions. The term seed vigor is used to describe the response of seeds to non-optimal conditions. Rapid and uniform germination and stand establishment under field conditions are indications of good seed vigor.[2]

Germination Conditions

Temperature is one of the most important environmental factors affecting both the percentage and rate of germination. Seeds germinate most quickly and uniformly in their optimal

(Continued on page 2)

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(Continued from page 1)

temperature range.[1] For example, at 86°F pepper seed germinate in 8 days, while at 58°F, it takes 13 days for seed to germinate.[3] The amount of heat required for 50% germination is expressed as the heat sum (similar to degree days). Crops such as onion, leeks, and celery have relatively high heat sum requirements and germinate more slowly than other crops.[4]

Adequate moisture is necessary for seed germination, as the uptake of water by the seed starts the germination process. Good seed-to-soil contact is needed to allow seeds to take up water and stay hydrated.[1] Soil moisture contents of 50 to 75 percent of field capacity are usually best for promoting seed germination. At moisture levels above 75 percent, air spaces in the soil become filled with water, and the reduced availability of oxygen can slow root growth and result in root rot.[2] Good gas exchange in the soil is needed to remove carbon dioxide and replenish the supply of oxygen.[3] Moisture levels below 50% can slow the rate of germination. The emergence of the radical from the seed coat is the stage of the germination process that is most sensitive to moisture levels.[4]

While most seeds can germinate in the dark, some need light to stimulate germination. Lettuce and celery are examples of crops that need light to germinate. By contrast, tomato seeds germinate best in the dark, and light can inhibit the germination of some tomato varieties.[2,5] Once seedlings have emerged, they require adequate light levels to grow properly.

Managing Germination and Emergence

Germination testing: If seeds have been stored for over a year, they may have lower vigor and a lower germination rate. To evaluate the percent germination, wrap at least 25 seeds in a moist paper towel and keep them moist but not soggy at room temperature. Check the percentage of germination after five to ten days. Consider purchasing new seed if the germination percentage is below 85 to 90%.[1]

It is desirable to have all of the seed in a planting germinate at about the same time to achieve a uniform stand. Uniform growth after germination is also desirable. When possible, plant into a well prepared seedbed with even soil moisture and when soil temperatures favor rapid germination to maximize stand uniformity. In greenhouse plantings, use germination heat mats to provide even temperatures. For direct seeding in the field, a fine-textured seedbed, which allows for good seed to soil contact, and a uniform planting depth will help maximize stand uniformity.[1,2] Seed priming can help increase the rate of germination and improve stand uniformity.

Adjust the seeding rate based on the percent seed germination rate and soil temperatures at planting. Stands that are too dense can result in spindly seedlings, while sparce stands are a waste of space and can result in uneven crop development.[5] The optimum seeding depth varies by crop. In general, small-seeded crops (lettuce, brassicas) germinate and emerge best at a shallower planting depth, while germination and emergence of larger-seeded crops (bean, cucurbits) is better when a deeper planting depth is used (table 1).[5]

Table 1. Recommended seeding depths and germination temperatures.[1,5]

Crop	Seeding Depth (inches)	Germination Temperature (°F) Optimum Range (Optimum)
Broccoli	¼	45-95 (85)
Carrot	¼	45-85 (80)
Lettuce	⅛	40-80 (75)
Onion	¼	55-95 (75)
Tomato	¼	70-95 (85)
Watermelon	½	75-95 (90)

Seedling Development

The optimal temperatures for seedling growth can be different (often lower) than the optimal temperatures for seed germination. Seedling growth is usually slower at lower temperatures and faster at warmer temperatures within the range of temperatures for acceptable growth. In greenhouse systems, uniform 24-hour temperatures usually favor germination and emergence, but vegetative growth of seedlings may be best when night-time temperatures are lower than day-time temperatures.[1]

Deep watering helps promote good root development and growth of the roots deeper into the soil profile. Shallow watering can result in the development of a shallower root system and lead to higher plant stress later in the season. Overwatering can lower oxygen levels in the root zone and promote damping-off and root rots. In greenhouse systems and transplant production, different watering amounts and schedules may be needed for seeds and seedlings. When direct seeding, sprinkler irrigation may be needed initially to promote uniform emergence and prevent soil crusting. Growers can then switch to drip irrigation after emergence.[3,5]

Sources:

[1] Stivers, L. 2017. Understanding seeds and seedling biology. Penn State Extension. https://extension.psu.edu/understanding-seeds-and-seedling-biology.
[2] Heuvelink, E. 2018. Tomatoes, 2nd edition. CABI
[3] Stivers, L. and DuPont, T. 2012. Seed and seedling biology. Penn State Extension. https://extension.psu.edu/seed-and-seedling-biology.
[4] Brewster, J. 2008. Onions and other vegetable alliums. CABI.
[5] Maynard, D. and Hochmuth, G. 1997. Knott's handbook for vegetable growers, fourth edition. John Wiley & Sons. New York.

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For additional agronomic information, please contact your local seed representative.

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