Seed Germination and Stand Establishment

Thomas G Chastain
CROP 200 Crop Ecology and Morphology
Seed Germination and Stand Establishment

Wheat Seed Germination

- Seedling Emergence
- Coleoptile Elongation and Root Development
- Radicle Emergence
- Imbibition
- Soil Surface
- Seedling Development
Seed Germination

- **Seed Germination** is defined as the following: A physiological process in which a partially or fully differentiated embryo resumes growth after a period of rest.
- Germination is a three phase process:
  1. Imbibition
  2. Preparatory period
  3. Radicle emergence

![Germination of grass seed](TG Chastain photo)
Imbibition (water uptake) by the seed and O$_2$ uptake are required for activation of enzyme systems and oxidative phosphorylation. Seeds draw water from the soil.

Imbibition is a physical process (dead seeds will take up water!) of water uptake that is governed by:

1. Seed water potential
2. Seed size
3. Seed coat permeability
4. Seed-soil contact
5. Soil hydraulic conductivity
Seed Germination - Imbibition

Good seed-soil contact
Fine, firm seedbed

Seed water uptake affected equally by liquid and vapor transport mechanisms

Poor seed-soil contact
Crop residue, clods, stones

Reduced soil hydraulic conductivity results in poor liquid transport to seed so vapor transport is more important

\[ \Psi = -2 \text{ MPa} \]

\[ \Psi = -100 \text{ MPa} \]
Seed Germination - Imbibition

- Seeds draw water from the soil until the critical seed water content for germination is reached. Seed will typically take up water equivalent 2-3 times their original dry weight.

- The time from planting to radicle emergence is 24 hours for wheat and 48 hours for barley. The critical seed water content for both species is about 300 g/kg FW but barley takes about one day longer to reach this seed water content.

- Critical seed water contents for seed germination in other crop species are: peas 500 g/kg FW, maize 310 g/kg FW, rice 270 g/kg FW.
The imbibition phase of seed germination depends on substrates stored in the embryo axis. Sustained seedling growth and development depends on the enzymatic breakdown and mobilization of stored reserves in the cotyledons or endosperm.

As seeds take up water, substances such as sugars, organic acids, amino acids, and proteins leak out of the seed into the soil. This continues until cell and organelle membranes are repaired. This leakage is a signal sensed by pathogens and other pests to attack the seedling. Seed are treated to protect them from pest attack.
During this phase, H₂O and O₂ uptake are not as rapid as during imbibition.

Once the seed is hydrated, several processes take place including membrane repair – mitochondrial membranes are damaged by drying during seed maturation.

Mitochondria of sunflower seed: intact membranes prior to drying of seed (top), dry seed showing dessication-damaged membranes (bottom), photos from Attucci et al., (1990).
Seed Germination – Radicle Emergence

- Protein synthesis is required. Water uptake is again rapid in this phase. Increased water uptake is due to a decrease in the osmotic potential as a result of high concentrations of low molecular weight products of stored reserve hydrolysis.

- The time from radicle emergence until seedling emergence from the soil varies with planting depth and soil temperature given adequate soil water.

Tall fescue seedling (TG Chastain photo)
Seed germination can only take place within a range of temperatures.

There is a minimum, maximum, and optimum temperature (cardinal) for germination of each crop species.

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<thead>
<tr>
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<tbody>
<tr>
<td>Corn</td>
<td>8-10</td>
<td>32-35</td>
<td>40-44</td>
</tr>
<tr>
<td>Rice</td>
<td>10-12</td>
<td>30-37</td>
<td>40-42</td>
</tr>
<tr>
<td>Barley</td>
<td>3-5</td>
<td>19-27</td>
<td>30-40</td>
</tr>
<tr>
<td>Muskmelon</td>
<td>16-19</td>
<td>30-40</td>
<td>45-50</td>
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Seed Germination – Chemistry

• Carbohydrates, storage proteins, and oils are stored in seeds to provide energy for germination and subsequent seedling development. This energy comes from the respiratory oxidation of these compounds.

• The carbon skeletons of compounds oxidized during germination can be utilized as building blocks for cell walls and membranes, proteins, and nucleic acids, etc. by the developing seedling.
Carbohydrates are stored in seeds of grasses and small grain cereals in starch grains in the endosperm as amylose or amylopectin.

Endosperm cells with starch grains

Microscopic view of border of endosperm with testa (top) Andrew Huber photo.
Seed Germination - Carbohydrates

- GA (gibberellic acid), a hormone, is synthesized in the embryo after H₂O uptake.
- GA stimulates the expression of the enzymes α- and β-amylase, α-glucosidase, and others in aleurone cells.
- Starch stored in the endosperm is degraded by these enzymes to maltose and glucose, and transported to the developing seedling as sucrose.

Longitudinal section of corn seed
Seedlings emerge in many species through elongation of the hypocotyl. For the seedling to become established, the elongation of the hypocotyl must cease and leaf development must begin.

- The elongation of the hypocotyl ceases when exposed to light in a process known as de-etiolation.
- Seedlings grown in dark are etiolated. Exposure to red and blue wavelengths result in de-etiolated normal seedlings. Far-red light exposure results in de-etiolated seedlings without chlorophyll.

Arabidopsis seedlings (top), light and the EM spectrum (bottom)
Phytochromes are photoreceptor (light) molecules consisting of an apoprotein attached to a linear tetrapyrrole (four pyrrole rings, A-D) chromophore.

- The Pr form of phytochrome is receptive to red light and the Pfr from is receptive to far-red light.
- Red light triggers an isomeric change of the double bond between the C and D rings of the tetrapyrrole structure of the Pr chromophore, resulting in the conversion to the Pfr chromophore and a physiological response in the plant. Far-red light converts the Pfr chromophore back to the Pr chromophore.
Pr form has an absorbance peak at 660 nm while Pfr form has a peak at 730 nm.

The light wavelength received by the chromophore controls germination and seedling green up. For some seeds, this prevents germination in an unfavorably shady habitat.

Smith (2000)
Stand Establishment

Stand establishment is the most important event in the development of crop yield.

There are 3 phases of seedling development that lead to establishment of the stand:

1. **Heterotrophic phase** – imbibition to emergence. Seedling growth depends on stored reserves in seed.
2. **Transition phase** – initiation of photosynthesis, but seed reserves remain available for growth.
3. **Autotrophic phase** – growth is dependent on photosynthesis alone - stand is established.

Heterotrophic phase - canola cotyledons after seedling emergence (TG Chastain photos)

Transition phase - appearance of primary leaves in canola seedlings

Autotrophic phase - appearance of secondary leaves, senescence of cotyledons
Stand Establishment

Factors affecting stand establishment:

• **Seed quality** – Seed vigor, seed size or weight, physical condition of seed, seed protein content, seed germination capacity.

• **Management practices** – Seedbed preparation, seeding rate and row spacing (plant population), seeding depth and date, seeding method (drill, broadcast, no-till), seed treatment.

• **Environmental conditions** - Soil water content, seedbed temperature, seedbed physical structure, oxygen.

Direct-seeding wheat (John McManigal photo)
• **Seed quality.** Seed companies screen wheat and barley seed and market the large seed separately.

• Large seed produced better stands than smaller seed from the same harvested crop. Large seed produced greater tiller production and grain yield than small seed.

<table>
<thead>
<tr>
<th>Seed size</th>
<th>Shoots (grams)</th>
<th>Roots (grams)</th>
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<tbody>
<tr>
<td>Large</td>
<td>1.14</td>
<td>0.39</td>
</tr>
<tr>
<td>Small</td>
<td>0.73</td>
<td>0.23</td>
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Stand Establishment

**Seed quality.** The coleoptile protects the seedling shoot as it emerges through the soil. Wheat seed with long coleoptiles emerge better than those with short coleoptiles. This is important when seed is planted deep to place seed in stored soil moisture.

Coleoptile length varies with *Rht* alleles with tall wheat having the longest coleoptiles.

Emerging seedlings showing coleoptiles (white) TG Chastain photo
Stand Establishment

- **Management and Environment.** Camelina is a spring annual oil seed crop in the mustard family.
- Camelina is insensitive to method of planting and has peculiar responses to date of planting depending on production environment (Schillinger et al., 2012).