Uptake of water by seeds is an essential step toward germination.

Water potential of the cells:

\[ \psi_{\text{cell}} = \psi_{\pi} + \psi_{m} + \psi_{p} \]

- \( \psi_{\text{cell}} \) – cell water potential
- \( \psi_{\pi} \) – osmotic potential
- \( \psi_{m} \) – matric potential
- \( \psi_{p} \) – pressure potential

Water potential of the dry seed is very low:

- \( \psi_{\text{dry seed}} = -350 \text{ to } -50 \text{ MPa} \)
- \( \psi_{\text{germination}} = 0 \text{ to } -2 \text{ MPa} \)

Definitions

Water potential (\( \psi \)): expression of the energy status of water. The movement of water occurs down the energy gradient. Pure water has the highest water potential of zero.
Water moves from high to low potential
- The values of $\psi_n$ and $\psi_m$ in the cell are negative, $\psi_p$ is positive
- $\psi_{cell}$ is negative, zero in fully turgid cell

Movement of water to the seed depends on $\psi$ of the soil immediately surrounding the seed
- Water-holding capacity of the soil
- Seed-soil contact
- Seed size, texture and shape
- Soil $\psi \Rightarrow$ sand vs. clay

### Factors affecting water uptake in seeds
- Water uptake occurs regardless seed viability or dormancy
- Three characteristics: sharp front separate dry and wet portions of seed; swelling reaches new regions; increase water content of wetted area
- Metabolism can commence

### Phase I
- Water uptake occurs regardless seed viability or dormancy
- Three characteristics: sharp front separate dry and wet portions of seed; swelling reaches new regions; increase water content of wetted area

### Phase II – Lag phase
- $\psi_c$ no longer plays an important role
- $\psi$ does not exceed $-1$ to $-1.5$ MPa
- Major metabolic events in preparation for radicle emergence

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*Photo by Dr. Casini, Argentina*
Water uptake in seeds

Phase II – cont.
• Dormant seeds can remain in Phase II for months or years
• In Phase II seeds remain tolerant of desiccation

Water uptake in seeds

Phase III –
• Limited tolerance to desiccation after embryo growth has been initiated
• Only live seed enters this phase
• Initiation of growth will occur when $\Psi_p$ exceeds the mechanical restrain of the enclosing tissue

Seed & Soil

Water content

Oxygen requirements

• Most seeds require $O_2$ to germinate
• $O_2$ requirement depends on species and seed dormancy
• Also on seed composition: oily seeds (lettuce, sunflower, radish, turnip, soybean, flax) below 2% oxygen tension; starchy seeds (rice, wheat, maize, sorghum) can germinate below 1% oxygen tension

The Atmosphere

• 21% Oxygen
• 0.03% Carbon dioxide
• 79% Nitrogen

The Atmosphere
Oxygen consumption in seeds

**Phase I**
- Sharp increase in O$_2$ consumption
- Attributed to activation and hydration of mitochondrial enzymes

**Phase II**
- Lag phase
- Hydration is completed and pre-existing enzymes are activated
- May occur due to slow down in oxygen uptake through the seed coat and surrounding structures

**Phase III**
- Second respiratory burst
- Increase in activity due to newly synthesized mitochondria and respiratory enzymes
- Increased oxygen supply through rupture of seed coat

**Phase IV**
- Occurs only in storage tissue
- Coincides with senescence following depletion of stored reserves

Length of phases I – IV vary according to species, rate of imbibition, seed coat permeability to oxygen, temperature, and metabolic rate.

During germination, a steady supply of substrates for respiration must be present.
### Anaerobic conditions

- Can last a few hours to several days
- Can be prolonged by sowing under water
- Many species can germinate under water but radicle is stunted
- Rice and barnyard grass will germinate under $O_2$-free environment, coleoptile elongates but root is inhibited

### References: