The Temperature Factor

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Temperature Factor

- Optimum temperature for photosynthesis in C3 plants is lower than that for C4 plants and the rate of photosynthesis is greater for C4 across most of the range in temperatures. Temperatures outside the optimum for can have serious consequences for crop yield.
- Extreme temperature stress can cause injury or death of the plant.
- The plants’ response to temperature stress depends on genetic constitution of the plant, the timing of the stress during plant development, and the duration and the magnitude of the stress.
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- **Low Temperature Stress Response Types:**
  
  - **Chilling-sensitive plants.** Plants are injured or killed by temperatures above freezing.
  
  - **Freezing-sensitive plants.** Plants are injured or killed when ice forms in cells.
  
  - **Freezing-tolerant plants.** Plants can survive some ice formation without injury or death. Extreme low temperatures or long duration of cold can cause injury or death.

Date palms (USDA photo)
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- Cellular events during freezing:
  - **Extracellular Freezing** – super-cooling of the cell and extracellular solution precedes freezing. As the amount of extracellular ice increases, the solute concentration of the extra-cellular solution is increased, causing freezing point depression. Dehydration eventually causes collapse of the protoplast.
  - **Intracellular Freezing** - Ice formation can sometimes be limited to vacuoles, but most plants tolerate little ice formation in the cell. Death results from protoplast destruction.
Cellular responses in freezing-sensitive and tolerant plants:

- Osmotic loss of water occurs during freezing and cell surface area decreases.

- In cells that are not acclimated, the membrane is damaged by encytotic vesiculation while in acclimated cells membranes are preserved as exocytotic extrusions.

- After thawing, cell expansion causes lysis of the membrane in cells that are not acclimated, but in acclimated cells after thawing, the extrusions permit expansion of the cell.
Acclimation or cold hardening - tolerance to low temperatures can be achieved if plants are hardened at low temperature prior to exposure. Solutes, including sugars, certain proteins, and amino acids, accumulate at temperatures just above freezing.

- Sugars that accumulate in the vacuole decrease the amount of ice formed.
- Sugars may also protect the cell against freeze-induced dehydration.

Water soluble carbohydrate (sugars and fructans) accumulation in spring wheat, winter wheat, and spring x winter crosses. (Equiza et al., 1997)
Low temperature stress during vegetative development causes reduced plant population and/or a reduction in branching or tillering.

Freeze or frost damage at the 2-leaf stage in spring barley, if severe, will cause chlorosis of the plant. The plants will recover the green color but will produce less grain than expected.
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- High temperatures can have direct inhibitory effects on growth and development or indirectly, can intensify water deficit stress. High temperatures can damage leaves, inhibit tuber formation in potato, and reduce viability of pollen.
Some plants are very tolerant whereas others are not very tolerant of heat stress. There are 3 mechanisms that plants employ to tolerate heat stress:

- **Transpirational Cooling** - lowers leaf temperature during periods of high temperature if sufficient water is available.

- **Acclimation** - tolerance of high temperatures can be achieved if plants are hardened at moderately high temperature prior to exposure. Must be greater than 38°C in grasses.

- **Heat-Shock Proteins**.
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- Gradual increase in temperature permitted maize plants to acclimate to high temperature stress. Plants that were acclimated had greater photosynthesis at the same temperature than those exposed to a rapid increase in temperature.

- Inhibition of photosynthesis was not related to stomatal closure as transpiration was increased in proportion to increased temperature.

(Crafts-Brandner and Salvucci, 2002)
Heat reduces the rate and duration of seed filling in wheat.

The timing of the high temperatures in relation to grain development is important. Heat early in development (10 days after anthesis) reduced grain yield more than similar temperatures late in development of the grain (15 or 20 days after anthesis).

Starch synthesis is reduced at high temperature. Protein synthesis is reduced but not to the same extent evident in starch deposition.

Heat can result in reduced seed weight and seed germination.

Timing of heat impacts wheat grain yield (adapted from Gibson and Paulsen, 1999)
The effect of high temperatures during flowering and pod development were measured over a 30-year period near Pendleton Oregon.

Pea is very sensitive to high temperatures and will die when 35°C is exceeded.

Maximum daily temperatures below 26°C had no effect on fresh pea yield in eastern Oregon. Daily temperatures above 26°C depressed yield in an exponential manner.

High temperature effects during flowering and pod development on yield of green peas (Pumphrey and Ramig, 1990)