Chilling Injury

Questions from Last Time;

Q: What happens to plasmodesmoda during freezing?

Q: Why are new buds so susceptible?

Chilling Injury

Typically occurs in plants from sub-tropical and tropical origin

Chill-sensitives injured or killed by temperatures between 0-15°C NOT FREEZING TEMPS.

Long exposure usually required (days, weeks), the lower the temperature the shorter the exposure time.

Chill-resistant plants are not affected by lower temperatures.

Examples of Chill Resistant Plants

Fruit/Veg: Green pepper, tomato, cucumber, sweet potato, banana (fruit is very susceptible).

Ornamentals: coleus, Gloxinia, peace lily, Passiflora, Episcia reptans. The ornamental genus Episcia (African violet) is especially sensitive and damaged at 10°C.

Morphological Symptoms: Slow growth, foliage gets water soaked lesions, chlorophyll loss, discoloration.

Flowers become discolored and brown

Fruits off -flavors develop, lack of ripening.

Roots- collapse of tissue, flaccidity, browing.

Poor establishment of seedlings, esp since soil is cold in spring.

Growth index of *Spathiphyllum* cultivars 45 days after exposure to 11C for 5 or 10 days.

Cultivar	Days of Chilling 0	5	10
Annette	370	224	182
Mini	380	194	202
Viscount	351	302	181

Growth index (cm^2)=[(plant width 1 + plant width 2)÷2] x plant height.
Control plants (0 days of chilling) grown at 18 to 32C.

Symptoms can be delayed:

Transfer of a chilled plant or organ (fruit) to warmer temperatures after receiving chilling temperatures will accelerate symptom development.

example: bananas in refrigerator do not show symptoms until moved to room temperature.

postharvest quality– sometimes symptoms and degradation occur quickly even though they appear fine at harvest.

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Physiological Symptoms

A decrease in photosynthesis in 4-6 year old avacado tress.

NCS field grown-- trees in the field and exposed to temperatures above 14°C at all times (covered with protective structures at night)

CS field grown – trees in field and exposed to 24 nights of temperatures between 8 and 19°C.

Container-Grown – grown outdoors and exposed to 24 nights of temperatures between 8 and 10°C.

RESULT: both CS field grown and container grown plants show a decrease in photosynthetic rate compared to NCS field-grown trees.

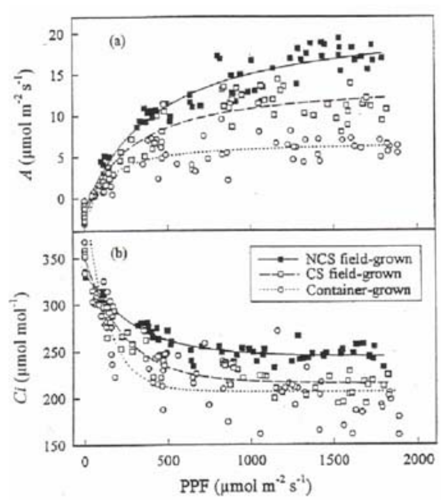
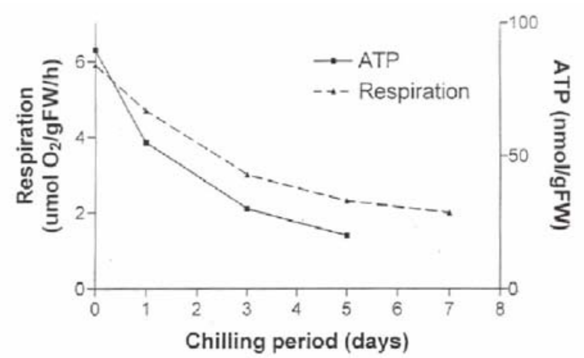


Fig. 1. Net CO_2 assimilation (A) and intercellular partial pressure of CO_2 (Ci) responses of field- and container-grown avocado trees ('Hass') to varying photosynthetic photon fluxes (PPF). The regression line for A (a) of noncold-stressed (NCS), field-grown trees is represented by $y = 22.08((-30.67 + x)/(427.43 + x))$, $r^2 = 0.94$; cold stressed (CS), field-grown trees is represented by $y = 14.17((-46.72 + x)/(250.05 + x))$, $r^2 = 0.86$; and container-grown trees is represented by $y = 7.16((-38.366 + x)/(172.12 + x))$, $r^2 = 0.84$. The regression line for Ci (b) for NCS, field-grown trees is represented by $y = 244.65 + 90.2\exp(-0.0034x)$, $r^2 = 0.94$; CS, field-grown trees by $y = 215.28 + 135.52\exp(-0.0041x)$, $r^2 = 0.92$; and container-grown trees by $y = 203.70 + 171.39\exp(-0.0056x)$, $r^2 = 0.87$.

Physiological Symptoms



A decrease in respiration rates and ATP synthesis accompany consecutive days in cold

Decrease in protein synthesis

Damage to membranes – why?

Physiological Symptoms

Green tomato fruit – exposure to chilling temperatures (5°C) for 0, 2, 7 or 14 d followed by 3 d at 20°C.

After 2 d of chilling degradation of starch and chloroplasts was observed.

After 7 d the chloroplast grana unstacked, chloroplast swells.

Mitochondrial membranes intact.

After 14 d the chloroplast is deformed, thylakoids disorganized and mitochondria showing signs of deformation. Plasma membrane intact.

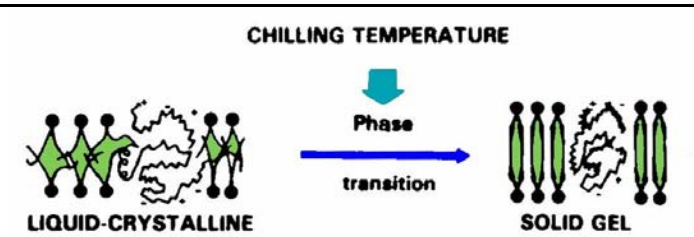
INDICATES CHLOROPLAST IS THE CENTRAL AREA OF DAMAGE (mostly the PSII reaction center (water splitting, oxygen evolving site.)

Physiological Symptoms

In non-green tissue the roots are the first places to show symptoms.

Chilling symptoms (like everything) vary between species, cultivar, tissue and stage of development.

ie. Seedlings much more sensitive than older plants and seeds are generally insensitive.



Mechanism of Damage

Membranes are usually fluid, but chilling temperatures induce a phase transition from liquid to gel state. There is localized tight packing of lipids and less flexibility, membrane loses integrity leading to:

1. an increase in permeabiltiy– aqueous channels develop in membranes and increase permeability.

2. Ion leakage – solute leakage and electrolyte imbalance. Cuke roots held at various temperatures (2,6, 10, 15 C) for different times and then placed at 20°C for 24 h.

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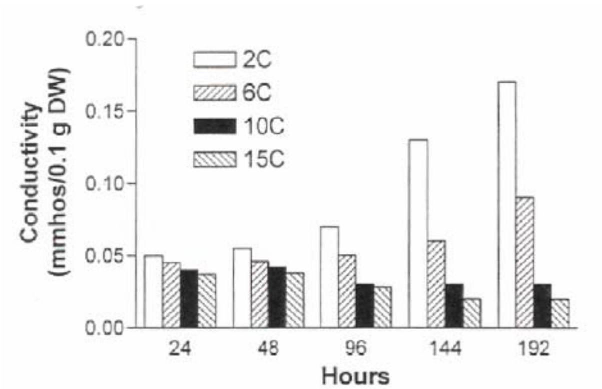


Changes in conductivity are indicative of ion leakage.

Mechanism of Damage

Membrane protein denaturation – Membrane enzymes decrease in activity, integral membrane proteins (light reaction proteins, ATPases, membrane transporters) all affected.

This affects ATP synthesis etc.

Also, enzyme activity involved in degrading oxidizing compounds decreases, allowing them to damage membranes. Decreased synthesis and increased degradation of these enzymes occur at chilling temperatures. Therefore the ability to deal with redox decreases. Chloroplast membranes photooxidize, electron transport in light reaction is disrupted, so reactive oxygen species are generated.

Mechanism of Damage

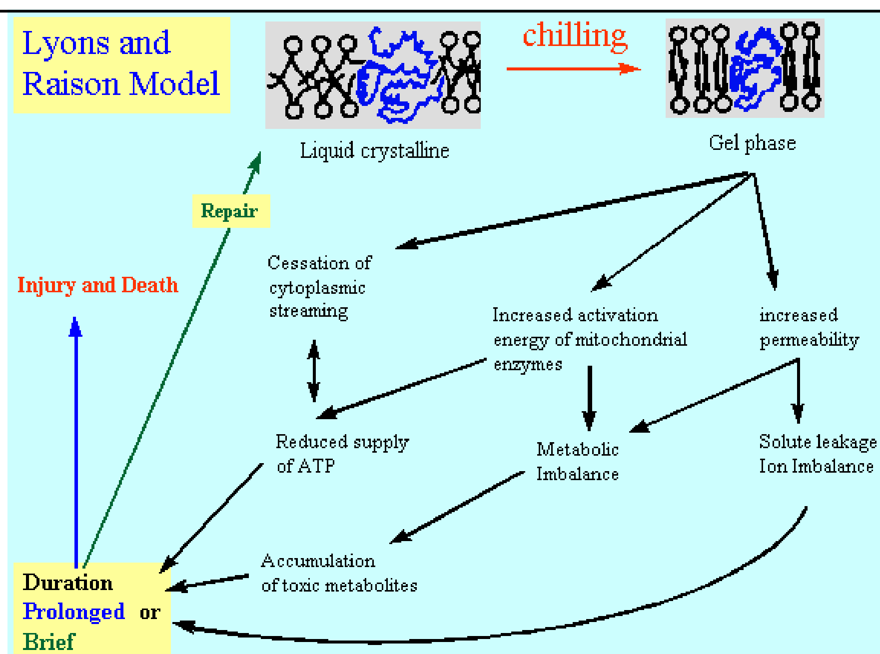
The temperature where phase transition occurs is the temperature that chilling injury symptoms become evident.

Sensitivity to chilling:

thylakoids > tonoplast > mitochondria > plasma membrane

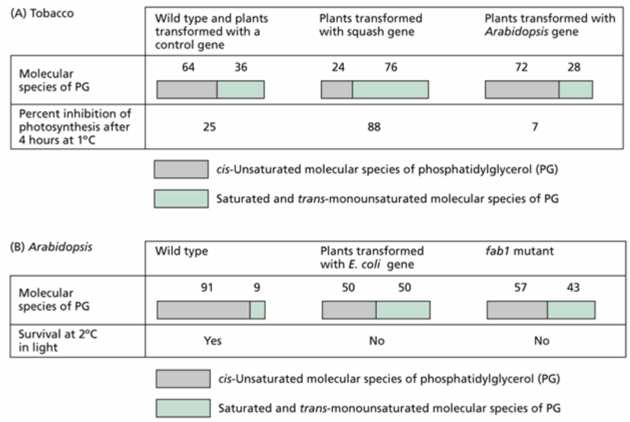
The progression is as follows:

1. **As thylakoids lose integrity there is a decrease in photosynthesis**
2. **As tonoplast looses integrity there is a release of toxic metabolites into the cytoplasm and a decrease in pH.**
3. **As mitochondrial membrane loses integrity there is a decrease in respiration.**
4. **As plasma membrane loses integrity there is solute leakage and ion imbalance.**



from Lyons, 1973

Transgenic remedies



Squash – chill sensitive, Arabidopsis – chill resistant

Studies with transgenics and mutants show how membrane composition differences protect from chilling injury independent of acclimation. The figure presents changes in relative levels of *cis*-unsaturated molecular species of phosphatidylglycerol (PG) in thylakoid membranes of (A) tobacco and (B) *Arabidopsis,* and the effect on sensitivity to chilling. (After Nishida and Murata 1996.)

Reversal

Phase transitions are reversible, to an extent.

Prolonged exposure to cold leads to buildup of toxic metabolites, low ATP production, excess electrolyte leakage and death.

Variation in Membrane Composition

Chill resistant and chill sensitive species have marked differences in membrane composition. Chill sensitives have a higher ratio of saturated fatty acid / unsaturated fatty acids in membranes.