PLANT GROWTH

by Dr. H. F. Mayland

Plant growth

Chilling temperatures in the range of 0 to 15°C greatly affect plant growth. Recent research has added to the knowledge of negative and positive effects of low temperature on growing plants.

Positive effects of chilling. Cool temperatures within the biokinetic range are required by many

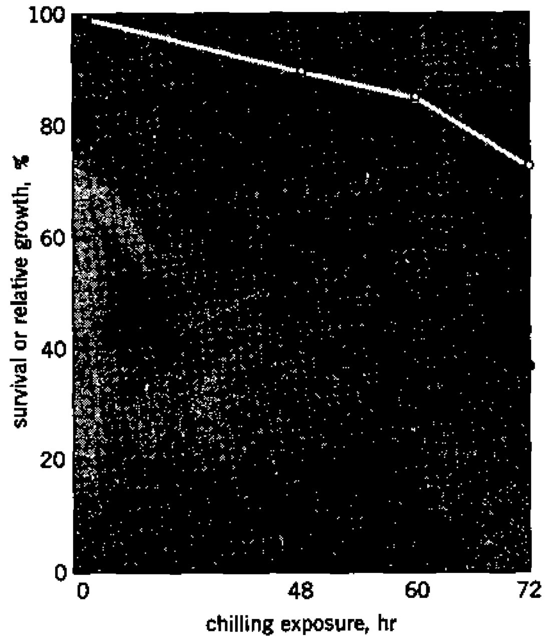

Fig. 1. Survival and relative growth (48 hr after return to 21°C) of Rainbow Flint corn seedlings subjected to 0.3°C and four exposure intervals.

plants to successfully complete their life cycles. Some plants need cold temperature to initiate bud development. Others need a period of cool temperatures before they will germinate. Night temperatures that are cooler than day temperatures are required for flowering in tomatoes and peas. Cool temperatures, along with other environmental factors, are required for development of cold-hardiness in cold-resistant perennials.

Negative effects of chilling. Many plants, especially those native to tropical and subtropical regions, are subject to chilling injuries that may prove fatal at temperatures 10°C above their freezing point. Chilling sensitivity may vary as a function of temperature and exposure time, species, growth stage, and other environmental conditions, but chilling temperatures that cause injury can be as high as 10.5°C, which is the case for bananas.

Germination. Chilling injury may occur when seeds are imbibing water at the initiation of the germination process. Lowering the temperature decreases the imbibition rates because of the increased viscosity of water and decreased membrane permeability. The extent of chilling injury during imbibition depends both on temperature and exposure time. Viability of cacao seeds, a tropical plant, is reduced to less than 1% at 6°C exposure, but the chilling injury may be reversed if the seeds are returned to warmer temperatures. However, when the seeds are exposed for 20 min to 4°C, the reaction is not reversible.

While wheat may germinate at slightly greater than 0°C, corn requires 5 to 10°C, and cotton requires greater than 10°C to initiate germination. Chilling cotton seeds during imbibition causes "nub root," resulting in poor stands. Dry lima bean and soybean seeds exhibit injury at the beginning of the imbibition period at 15 and 5°C, respectively. Injury is not observed if the seed has initially imbibed a portion of its water at room temperatures.

Growth. Young plants generally suffer more severely than do older plants exposed to similar chilling conditions. For example, 28-day-old velvet bean seedlings suffered 10% injury when exposed to temperatures of 0.5 to 5.0°C for 24 hr, whereas 14-day-old seedlings suffered twice as much injury when exposed to these same conditions. Exposing 10-day-old cotton seedlings to temperatures of 2 to 4°C proved fatal after 24 hr, but exposure for 48 hr was required to kill older seedlings.

While survival, or death, is frequently a measure of harsh injury, visual symptoms may also be seen. These include a general chlorotic appearance in cow peas, brown spots in cotton, white spots in soy beans, and white bands across the leaves in grasses, including corn.

Chilling reduces water and nutrient uptake and likewise translocation of photoassimilates. These processes frequently return to normal at warmer temperatures. R. P. Creencia and W. H. Bramlage reported that survival of Rainbow Flint corn seedlings decreased with increased exposure time to 0.3°C (Fig. 1). Corn seedlings that survived the exposure to 0.3°C continued to grow at increasing rates which, 96 hr after chilling, were similar to those of nonchilled plants.

Chilling of seedlings at certain growth stages may cause injury that is easily confused with herbicide damage. This type of chilling injury has been observed in potatoes and beans (Fig. 2).

Fig. 2. Trifoliate bean leaf showing injury caused by 2-hr exposure to −2°C at time when this trifoliate was in the growing tip (no ice present).

Polycellulosic deposits called callose plugs form in phloem sieve tubes of beans exposed to low temperatures, but plugs have not been found in tomatoes. Plugs also occur in peach trees, but at lower temperatures than required for tender plants. These callose plugs undoubtedly interfere with assimilate translocation in the plant.

Chilling injury reduces marketability of certain fresh fruits and vegetables held at temperatures between freezing and 10°C. Crops subject to chilling injury are usually native to tropical or subtropical areas and include such diverse species as bananas and cucumbers. The storage life of cucumber fruits is reduced by a factor related to the product of exposure time and the degree of chilling below 10°C.

Physiological responses. Chilling produces physiological changes within tissue that may be responsible for later development of visual symptoms. A characteristic change is increased respiration rate, possibly resulting from oxidative phosphorylation uncoupling. Another effect is increased ion leakage from plant tissue, possibly resulting from increased membrane permeability. This membrane damage may allow entry of disease organisms. Cold-hardened plants generally resist these forms of injury.

Chlorophyll synthesis is sensitive to low temperatures and tomato chloroplasts are known to degenerate at temperatures below 8°C. Resulting visual symptoms are chlorosis or striping of leaves, as mentioned earlier. *See* PHOTORESPIRATION.

Inflexibility of mitochondria membranes, one site of adenosinetriphosphate (ATP) synthesis, may result from low temperature. Cotton seedlings exposed to 5 °C showed continual decrease in ATP concentration with time. Plants chilled for 1 day and then returned to optimum temperatures restored their initial ATP concentration, but those chilled for 2 days did not (Fig. 3). Oxidative and photophosphorylation must be more sensitive to low-temperature inhibition than systems that use ATP. The decrease in ATP with chilling is avoided when seedlings are hardened to the cooler temperatures.

Enzyme responses. Dry-matter production at unfavorably low temperatures can sometimes be sustained by supplying specific metabolites. The substances may not be the same for all plants. At least part of the growth response following exposure to low temperatures is caused by a temperature-induced shortage of one or more essential metabolites. Thiamin, for example, compensates for a low-temperature-caused growth reduction in cosmos.

Ribonuclease development in lima bean seedlings normally parallels growth; however, under low-temperature stress, enzyme formation is reduced to a greater degree than is growth. The decreased enzyme formation may be due to an initial oxygen-dependent reaction, membrane damage, or blocking of intercellular air spaces during imbibition thus retarding oxygen diffusion.

Causes of low-temperature injury are still uncertain, but a theoretical basis is indicated by studies of enzyme behavior at low temperatures. At chilling temperatures well below the optimum, certain enzyme reaction rates no longer fit the Arrhenius formulation but possess an apparent activation energy (E) higher than that expected. There may be a rather sudden shift in E at a particular temperature, or a gradual transition. Thus a single enzyme reaction may become limiting to growth below a critical temperature where the activation energy changes to a high E value. This inhibition may then be expressed as a low-temperature injury reparable with a single substance.

J. K. Raison and R. M. Lyons have shown that the activation energy for succinate oxidation by mitochondria from chilling sensitive plant tissue increases from approximately 5 kcal/mole, within the temperature range of 11 to 25°C, to 35 kcal/mole between 1 to 10°C, indicating that a phase change occurs at about 10°C. No change in the activation energy was observed with mitochondria from chilling resistant tissues. Enzyme inactivation at chilling temperature may be attributable to an increase in intramolecular H-bonding, so that active centers lose their specific or essential configuration or are no longer exposed to the substrate.

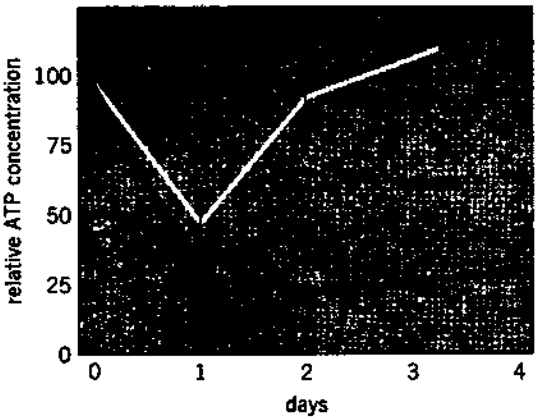

Fig. 3. Effect of chilling on subsequent adenosinetriphosphate (ATP) levels in cotton seedling leaves. Plants were chilled 1 or 2 days at 5°C and then returned to the greenhouse for 2 days.

For background information *see* PLANT GROWTH in the McGraw-Hill Encyclopedia of Science and Technology. [H. F. MAYLAND]

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