Plant Responses and Adaptation to Low Temperature

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Low temperature (LT) or cold stress is another major environmental factor that often affects plant growth and crop productivity and leads to substantial crop losses. Chilling stress results from temperatures cool enough to produce injury without forming ice crystals in plant tissues, whereas freezing stress results in ice formation within plant tissues. Plants differ in their tolerance to chilling (0-15ºC) and freezing (<0ºC) temperatures. Both chilling and freezing stresses are together termed low temperature or cold stress: the damage due to cold stress can range from chilling injury and freezing injury to suffocation and heaving. In general, plants from temperate climatic regions are considered to be chilling tolerant to variable degrees, and their freezing tolerance can be increased by exposing to cold, but non-freezing, temperatures; this process is known as cold acclimation. However, generally the plants of tropical and subtropical origins are sensitive to chilling stress and lack this mechanism of cold acclimation [9]. Low temperature may affect several aspects of crop growth; viz., survival, cell division, photosynthesis, water transport, growth, and finally crop yield.

Plant responses to low temperature

Cold or LT stress comprises of chilling (<20ºC) and freezing temperatures (<0ºC) hamper the plant growth and development in many ways. Chilling-sensitive plants exposed to low temperatures usually show water-stress symptoms due to decreased root hydraulic conductance and leaf water and turgor potentials.Cold stress effects on crop plant have been studied since long time in many economically important crops among which some of are chilling sensitive and unable to survive cold temperatures. Low temperature affects the plants in every stage of life starting from germination up to maturity.

Germination

Chilling injury is a serious problem during germination and early seedling growth in many plant species. For instance, optimum temperature range for germination of rice seed lies between 20 and 35°C, and the temperature of 10°C is cited as the minimum critical value below which rice does not germinate. There are many reports on positive correlation between germination at low temperature and root development at an early stage at low temperature; and between the germination and seedling establishment. Angadi et al. (2000) showed that the number of days to 50% germination in *B. napus* was only three days at 8°C compared to nearly 13 days at 2°C. This low temperature effect of slower and lower germination was even more pronounced with *B. rapa*. In *B. rapa*, there was greatly reduced germination at 3°C, and at 2°C, even after 20 days, 50% emergence was not reached (Angadi et al. 2000).

Growth and morphology

Low temperature stress inhibits various metabolic reactions thus preventing the expression of full genetic potential of plants which is expressed by different phenotypic symptoms. Some of the common LT injury in plants are reduced seedling growth, seedling discoloration, leaf yellowing, leaf whitening, white specks, white bands, withering after transplanting, a reduced rate of tillering, stunting and so on. It is well reported that plants at their seedling stage are very much sensitive to cold stress. At early stage of plant growth, various phenotypic symptoms in response to chilling stress comprise surface lesions, chlorosis, necrosis, desiccation, tissue break down and water soaked appearance of tissues, reduced leaf expansion, wilting.

Reproductive development

The reproductive phase faced to low temperature stress is influenced diversely in its different sub-phases. During the development of male gametophyte LT causes disruption of meiosis, tapetal hypertrophy, stunted development of pollen grain, anther protein degradation, pollen sterility, pollen tube deformation. In female gametophyte development its effects are characterized by reduced style and ovary length, disruption of meiosis, reduced stigma receptivity, callose deposition in style, damage to embryo sac components, and arrest of the fertilization process. At flowering LT may cause delayed flowering, bud abscission, sterile or distorted flowers, while at grain filling the source-sink relation is altered, kernel filling rate is reduced and ultimately reduced sized, unfilled or aborted seeds are produced.

Cell membrane damage

Extreme temperature injuries caused cold attack on the cell membrane. Cell membrane is damaged in two ways viz. disruption of protein lipid structure, protein denaturation and precipitation of solutes that indulges the membrane permeability. Due to low temperature stress the fatty acid become unsaturated and the lipid protein ratio of the membrane become altered which ultimately affect the membrane fluidity and structure as well. The flexible liquid-crystalline phase is converted in to a solid gel phase, thereby affecting the cellular function in different ways, viz. increased membrane permeability increases ion leakage, allows the entrance of undesirable anions and cataions into the cell, obstructs the exchange of essential ions, hampers the osmosis and diffusion processes, etc. All the phenomena are responsible disrupting cellular homeostasis..

3.5 Photosynthesis

Low temperatures may disturb the key organs of photosynthesis, including chloroplast and thylakoid membranes, causes swelling of plastids and thylakoid lamellae, vesiculation of thylakoid, accumulation of lipid drops and ultimately disorganization of entire plastid. Low temperature also disrupts the systems including electron transport, carbon cycle metabolism and stomatal conductance. Among the photosynthetic apparatus PSII is the primary target of damage under LT stress. Moreover, LT reduces the activity of stromal and carbon assimilation enzymes like Calvin cycle enzyme, ATP synthase, and restricts ribulosebisphosphate regeneration and limits the photophosphorylation.

Water movement and nutrient uptake

Cell membrane plays major roles in water and nutrient movement within and outwards the cell. Intra- and extracellular water and nutrient movement are inhibited due to LT., cold damage makes membrane permeable to undesired nutrients and ions and cause ion leakage; another is cell membrane and cell wall can be ruptured by cold which is also responsible for disrupting cellular homeostasis by destroying both intra and extracellular nutrient and water movement. Severe dehydration may also occur due to freezing of cell constituents, solutes and water. Freezing-induced increase in water viscosity is partly accounted for an initial decrease in root hydraulic conductance.

Yield components and yield

Reproductive phase products are the key components of economic yield and hence LT stress during the reproductive phase has significant economic and social consequences. All the adverse effect of cold stress ultimately lowers the yield of crop.

Mitigation of cold-induced damages

- Soil banking
- Wrapping of soil and/or plants
- Sprinkling
- Fogging
- Supplementary heat supply
- Mulching