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Low Temperature Stress in Maize

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Globally, maize is an important cereal crop which has taken its position as staple food crop after wheat and rice. Due to its versatility and wider adaptability to varied agro-climatic conditions, maize is an emerging crop. Increasing demand for maize crop lies in its numerous industrial applications (example: source for ethanol production), its significant use as sustenance for human and feed for animals. This crop is also known as "queen of cereals" due to its photo-thermic insensitive character and highest genetic potential among the cereals. It can be cultivated throughout the year i.e. in *Rabi, Kharif* and Spring season. Maize is predominantly a *Kharif* crop but from the past few years it has gained its importance for both as *Rabi* crop and spring season crop and also secured a significant place in total maize production in India. It is cultivated in nearly 205 Mha with a production of 1210 MT and productivity of 5878 kg/ha all over the world (FAOSTAT 2021). India produced 33.62 million tonnes in an area of 10.04 Mha in 2021-22 (agricoop.nic). In Haryana, it is grown on an area of 4.97 Kha giving 15.57 KT of production with 3133 kg/ha of productivity (anonymous, 2022).

Maize is particularly susceptible to low temperature injury. Cold stress during seed germination, seedling development and growth leads to decrease in yield (Li et al., 2019). Maize production can significantly go down due to cold damage during early spring. The rate of seed germination and seedling vigor are both decreased by cold (Zhang et al., 2020). When the temperature goes down below the optical range of cold stress can impair the cell membrane permeability, can damage the ultrastructure of embryonic root meristem cells and impairs the root development when occurs at imbibition phase.

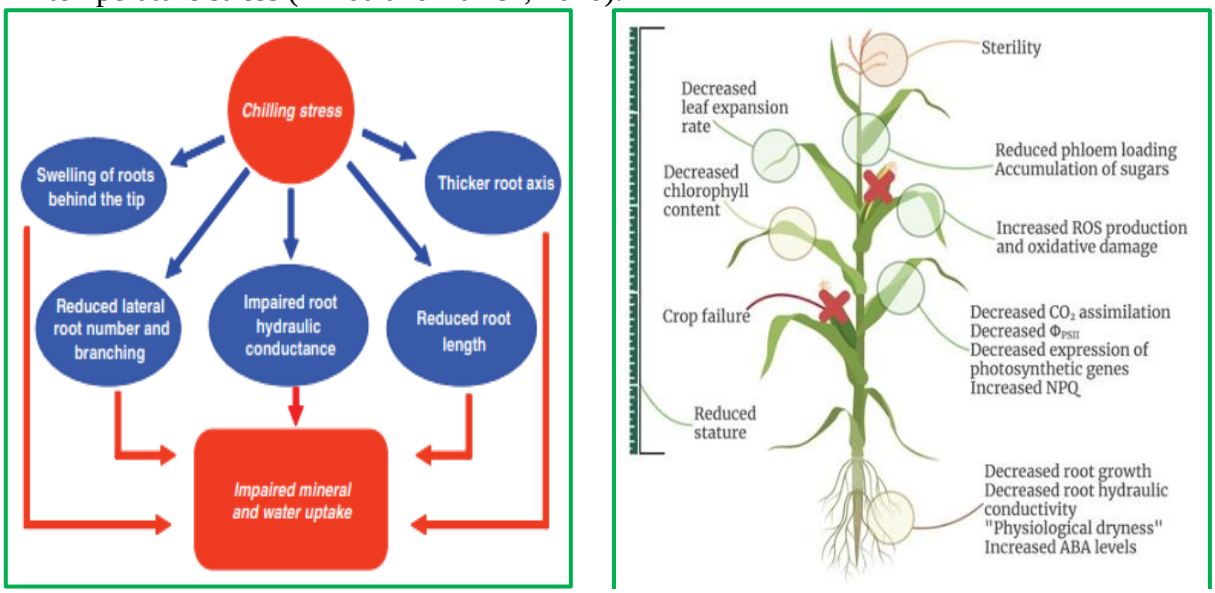
Table: Types of chilling stress (Leipner *et al.*, 2009)

Temperature (°C)		Effect on maize crop
<0	Freezing stress	Can cause disruption of structure and function of cells. Ice forms in the cell wall and intercellular spaces.
<5	Cold stress	Neither growth nor photosynthesis occurs and the plant depends on defence mechanisms to avoid damage and to survive
5-15	Chilling stress	Plants are still capable of adapting developmental processes in order to survive more unfavourable temperature conditions like during cold spells
15	Suboptimal conditions	Plants can acclimate rapidly but growth is retarded
20-30	Optimal conditions	Plants develop rapidly

Maize slows down its growth below 12 ℃ and eventually stops when the temperature fall below 6 ℃. An irreparable damage occurs when temperature fall out below 6 ℃.

Effects of low temperature stress in maize plants:

a) Low temperature prolongs the crop growth duration but reduces the growth rate, weakens the seedling and may also stops the grain filling prematurely.
b) Chlorophyll concentrations, leaf area, photosystem II (PS II) efficiency, and root shape are all adversely impacted by cold stress (Hund et al., 2007).
c) A brief bout of cold and chilling stress (<10 ℃ for 7 days) can possibly delay the onset of anthesis in maize plants (Hyashi *et al.*, 2016).
d) Cold stress significantly decreases the plant height and total biomass of maize
e) Abnormal tassel can be seen when low temperature stress occurs at reproductive phase
f) During seedling stage yellowing and burning of leaves can be seen under low temperature stress conditions
g) Exposure of plant to the cold stress during germination/emergence can causes the imbibitional chilling injury, delay and decrease in germination percentage, impaired mergence, seed rot and chlorosis.
h) Chilling injury causes wilting and browning of leaves and under severe conditions plant section can die.
i) Freezing stress, which happens at below-freezing temperatures, results in osmotic stress by dehydrating cells when extracellular ice crystals form, chilling stress imposes a direct temperature stress (Hinda and Zurich, 2020).



Effect of chilling stress on maize, Farooq *et al.*, 2009 (left) and Burnett *et al.*, 2022 (right)

Mechanism of chilling tolerance in maize plants:

a) Early vigour of maize is the ability to quickly produce assimilates for autotrophic growth after endosperm reserves are exhausted.
b) Morphological defense strategies such as thicker leaves resulting from thicker mesophyll and wax layers and a thicker cuticle were observed in maize tolerant plant.
c) Over production of compatible organic solutes or molecules having cryoprotective roles under low temperature stress conditions such as Glycinebetaine has osmo-protection function, and is known to protect protein, enzyme activities and stabilizes the membranes (Quan *et al.*, 2004).

Management of maize plants during low temperature stress

a) In maize, research was conducted to analyses the effects of the chemicals such as potassium chloride (KCL), gibberellin (GA), and 2-diethylaminoethyl-3,4-dichlorophenylether (DCPTA) on cold tolerance during germination were tested and authors suggested the combined applications of all three chemicals performed best in tolerating cold stress in maize (Wang et al., 2018).
b) Use chilling tolerant maize hybrids
c) Chilling effect can be minimized by selection of chilling tolerant inbred lines (Farooq e*t al.*, 2009).
d) Acclimation of maize seedling to prolong chilling stress can be done by pre-exposing the seedling to 4 ℃ chilling stress for a short period of time (Prasad, 1997).
e) Seed priming with $CaCl_2$ and KCl has also been found to improve chilling tolerance in different plant species including maize (Farooq *et al.*, 2008).
f) Frequent and light irrigation can be given to the maize seedling to protect the crop from frost injury.

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