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COLD TOLERANCE



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When temperatures remain above-freezing *i.e.* $>0^{\circ}\text{C}$ to $<10-15^{\circ}\text{C}$ it is called chilling

When temperature. remain below freezing *i.e.* $<0^{\circ}\text{C}$ it is called Freezing.

A. Chilling Resistance:

Chilling sensitive plants are typically tropical plants.

Temperate plants are generally tolerant to chilling injury.



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Effects of chilling stress on plants :

1. Reduced germination
2. Poor seedling establishment
3. Stunted growth
4. Wilting
5. Chlorosis
6. Necrosis
7. Pollen sterility
8. Poor fruit set / seed formation
9. Reduced root growth
10. Locked open stomato
11. ABA accumulation



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At subcellular level

12. Reduces membrane stability
13. Poor chlorophyll synthesis (affected)
14. Reduced photosynthesis & respiration
15. Toxicity due to H₂O₂ formation

Chilling Tolerance

Ability of some genotypes to survive / perform better under chilling stress than other genotypes is called chilling tolerance. It is because of chilling hardening, *i.e.* an earlier exposure to a near chilling temperature for a specified period as a result of which chilling tolerance of the concerned plants increases.



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Mechanisms of chilling tolerance:

1. Membrane lipid un-saturation
2. Reduced sensitivity of photosynthesis
3. Increased chlorophyll accumulation
4. Improved germination
5. Improved fruit / seed set
6. Pollen fertility

Sources of chilling Tolerance :

1. Late adopted breeding populations eg. maize
2. Germplasm (eg. That collected from high altitude , low temperature geographic regions)



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3. Induced mutants for cold tolerance
4. Cold tolerant somaclonal variants
5. Related wild species eg. Tomato

Selection criteria: Based on -

1. Germination test
2. Growth under stress (measured as plant dry matter accumulation)
3. Chlorophyll Loss under chilling stress eg. rice, cucumber, tomato (measured as seedling colour)
4. Membrane stability : (Assayed in terms of solute leakage from tissues)
5. Photosynthesis : Chilling injury to photosynthesis is assayed as variable chlorophyll fluorescence at 685 nm



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6. Seedling mortality

7. Seed / Fruit set

8. Pollen fertility (apply during injury at PMC)

B. Freezing Resistance

Freezing injury / Frost injury / cryo injury

Freezing Stress : Dormant state is conducive to freezing resistance, while resistance in actively growing tissue is rare : Thus Freezing resistance largely involves surviving freezing stress in such a manner as to enable subsequent regrowth when the temperature rises.

As water in plants cools below 0C, it may either

1. Freeze *i.e.* form ice or 2. Super cool without forming ice.



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Effects of freezing stress

1. Ice formation : Two types

A. Intercellular ice formation, B. Intracellular ice formation

Intercellular Ice formation: Initiation of ice formation on plant surface is sufficient to induce freezing of the internal (intercellular & xylem vessels etc.) water in most plant species. **Intracellular ice formation:** It is more lethal may be due to physical disruption of subcellular structure by ice crystal. Intracellular ice formation is the major and terminal freezing stress.

Extracellular ice formation in a cases the concentrations of extracellular solutes, there by water is withdrawn from the cells during extracellular ice formation. This creates water stress in the frozen tissue / plant.



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2. Membrane disruptions :

Freezing causes disruptions or alter the semipermeable properties of plasma membrane. Loss of solutes from the cells occur, Cells remain plasmolyzed even after thawing which is often called as frost plasmolysis. Cells may become highly effected due to uptake of excess water.

3. Supercooling :

Cooling of water below 0C without ice crystal formation is called supercooling . In plants water may cooldown to -1 to -15C in herbaceous sps and to -4 to -45C in hardy trees. This becomes possible apparently because internal ice nucleators are absence in such cases. This is regarded as an important. Mechanism of freezing avoidance



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4. Stress due to external factors : Consequent to freezing

- 1) Ice sheet formation below and above the ground causes reserve depletion anoxia etc. in plants.
- 2) Tissues killed during freeze-thaw are highly prone to pathogen attacks
- 3) Auto toxicity may occur



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Mechanism of Freezing resistance.

1. **Freezing avoidance** : The ability of plant tissues / or genes (but the whole plants) to avoid ice formation at sub zero temperature is called freezing avoidance. Supercooling is a mechanism of freezing avoidance.

It is controlled by

1. Lack of ice-nucleators
2. Small cell size
3. Little or no intercellular space
4. Low moisture content
5. Barriers against external nucleators
6. Presence of antinucleators



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2. Freezing Tolerance : Ability of plants to survive the stresses generated by extra cellular ice formation and to recover and regrow after thawing is known as freezing tolerance.

The various components of freezing tolerance are as follows:

- 1) Osmotic adjustment
- 2) Amount of bound water
- 3) Plasma membrane stability
- 4) Cell wall components properties
- 5) Cold-responsive proteins Eg. ABA



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Sources of freezing tolerance

1. Cultivated varieties
2. Germplasm lines
3. Induced Mutations
4. Related wild species Eg. Wheat *Agropyron* sps; rye, Barley – *H. jubatum*, *H.brachyantherum x H.bogdanii*, *H.jubatum x H.compressum*, Oats – *Avena sterilis*
5. Transgenes : Eg. chemical Synthesized antifreeze protein gene, ala 3, in tobacco



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Selection criteria:

Based on

1. Field survival
2. Freezing test in laboratory
3. Cryo freezing
4. Osmoregulation



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Problems in breeding for freezing tolerance

1. Freezing Tolerance is a complex trait & involves several components. So, it is not readily measurable under field conditions
2. Breeding work under field conditions is highly influenced by other environmental factors and biotic stresses
3. Due to large G X E for the trait field survival shows poor heritability
4. Freezing tolerance also shows a large GXE interaction which limits progress under selection
5. Laboratory tests are yet to be developed to screen large breeding population