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CHILLING STRESS: HOW IT AFFECTS THE PLANTS AND ITS ALLEVIATION STRATEGIES

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ABSTRACT: Low temperatures have been reported to be having far reaching effects on all plant species. The effects, in turn depend on the low temperature sensitivity of each and every plant species. In nature, the effects of various stresses may be seen overlapping thus the effects may be specific or non-specific. The effects in response to low temperature can be well ameliorated by the exogenous application of various protective molecules *viz.*, proline, glycine betaine, trehalose. Various cold tolerant transgenic crops over-expressing these molecules have also been developed.

INTRODUCTION: Every plant species has its own of temperature range within which it shows maximum growth and development and any deviation from this range, above or below it, hampers its overall performance. Sub-optimum temperatures have been proved to be having appreciably negative effects on various agricultural and horticultural crops resulting in heavy yield losses. Since cold stress invokes multiple effects and numerous complex mechanisms **Fig. 1** come into play in response to injuries and adaptations in cold-stressed plants¹³ thus, the overall effects have been rightly termed as a complex syndrome than a single response

Effects on Plants: The effects of cold stress, in turn depend on the low temperature sensitivity of each and every plant species.

Crops of tropical and sub-tropical origin, in particular, are more chilling sensitive *e.g.* rice (*Oryza sativa*), maize (*Zea mays*), chickpea (*Cicer sp.*). Other economically important crops suffering cold induced huge yield losses include soybean (*Glycine max* Linn.), cucurbits (*Cucurbita sp.*) and various cereal crops²⁵.

Though, the primary site of cold injury and hence electrolyte leakage is plasma membrane¹ in all the plants, however, in nature the effects in response to various stresses may be specific or non-specific *i.e.* they may overlap *e.g.* effects of cold and draught stress may overlap as shown in **Fig. 2**. To alleviate the harmful effects of cold stress, plants may accumulate various cryoprotectants. This article summarises the role of some of these protective molecules.

Proline: Proline is a well establish protective molecule and has been reported to impart protection against cold stress to many plants by not only maintaining its osmolarity but also acting as molecular chaperon thereby stabilizing the structure and hence functioning of crucial proteins and enzymes².

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It also protects the plant by maintaining the double stranded structure of genetic material *i.e.* DNA¹⁶ and by up-regulating the anti-oxidative stress machinery²³. Thus, if exogenously supplied, proline can well mitigate the harmful effects of cold stress as reported by Kumar¹⁴ in cold stressed chickpea.

Proline supplemented chickpea plants exhibited improved pollen viability, pollen germination and pollen tube growth along with better flower and pod retention. Similarly, proline conferred appreciable cold tolerance to rapeseed plants as well¹⁰.

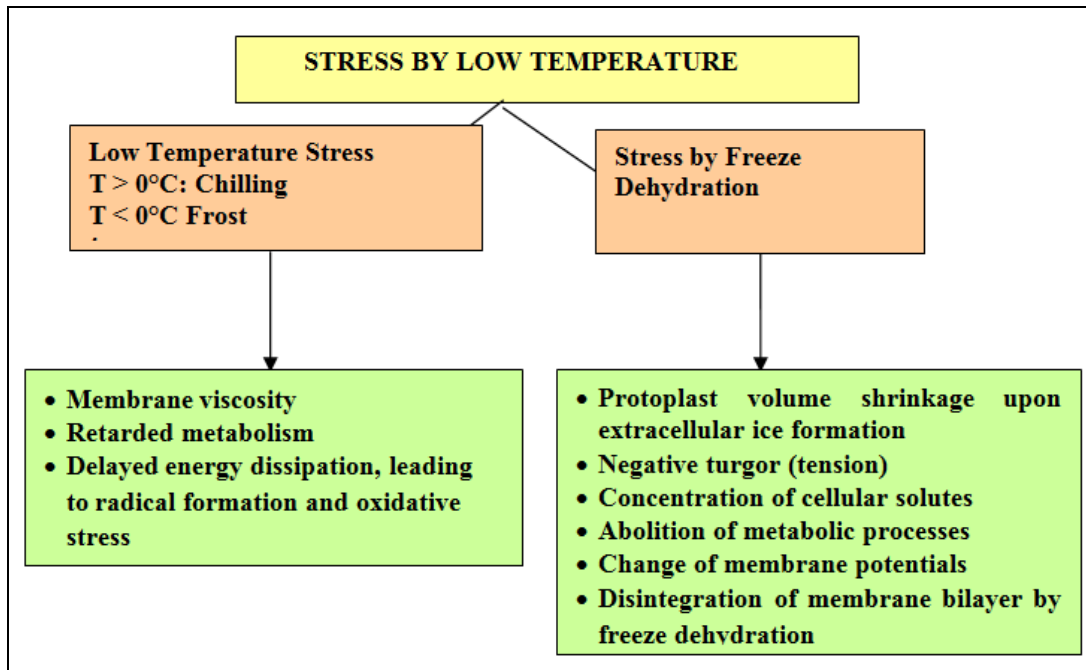


FIG. 1: THE COLD STRESS SYNDROME OF PLANTS

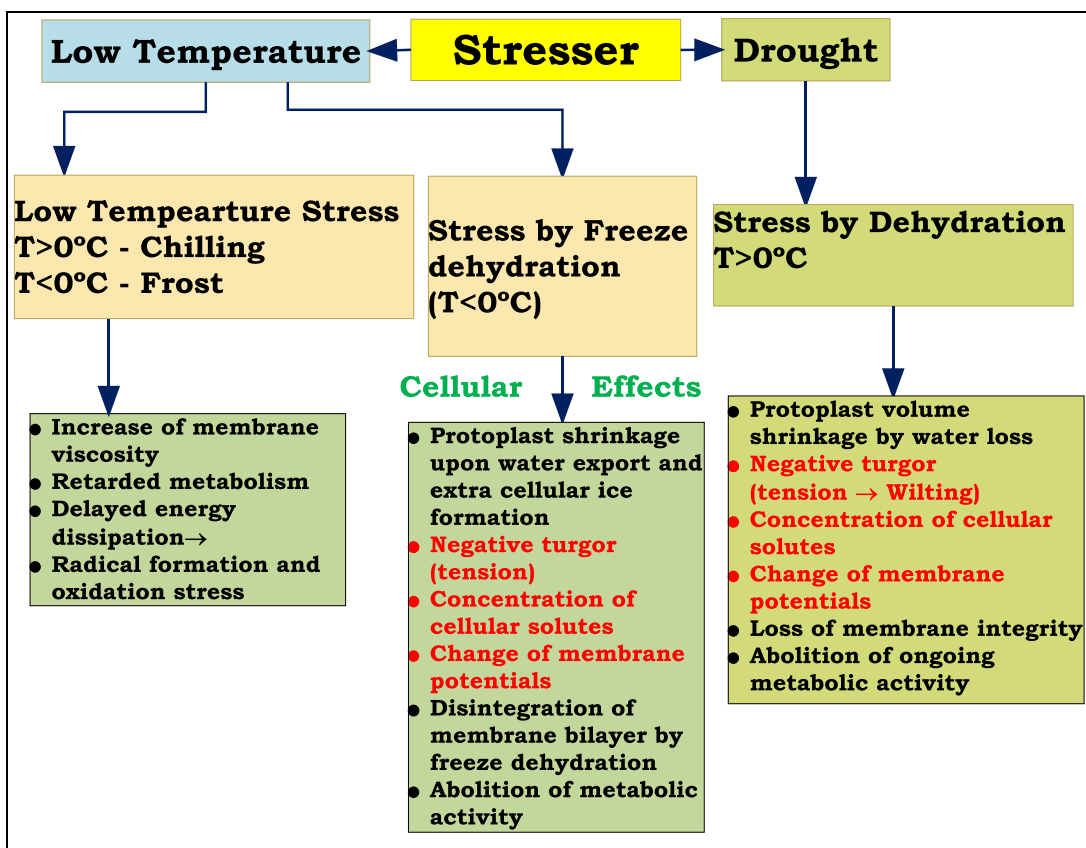


FIG. 2: STRAINS PRODUCED BY COLD AND DROUGHT IN PLANT TISSUES

Glycine Betaine: Glicine betaine (GB) is a quaternary ammonium compound and has been proposed to be an effective cryoprotectant as it protects the cold stressed plant plants from photoinhibition induced damage to photosynthetic machinery⁴ by protecting the various components of PSII¹⁵ and also as a molecular chaperone. Exogenously supplied GB improved the performance of tomato plants by¹². Similarly, GB supplemented sweet pepper plants also performed better than untreated one under cold stress²⁸ which corroborated similar reportson wheat³¹ and other grain crops²⁵.

Trehalose: Trehalose, an alpha linked disaccharide, has been proposed to be playing protective roles under various abiotic stresses including cold and freezing⁹. There are numerous reports of trehalose levels going up under low temperatures rice in Arabidopsis²⁶ and rice²⁰. Thus, exogenously

supplied trehalose thus can well protect not only cold stressed plants as proved in Arabidopsis⁶ but also yeast⁷ and even of *Cryptococcus laurentii* and *Rhodotorula glutinis*¹⁷.

The protective effects of trehalose have been credited to its membrane stabilizing ability and depression in phase transition temperature of biomembranes and remains amorphous even under completely dehydrated conditions²⁴.

Transgenic Approach: The protective molecules, discussed above don't seem to accumulate in sufficient amounts so the exogenous treatment has been proposed or the plants may be even genetically modified to over-accumulate specific molecule which in turn can well impart cold tolerance to the targeted plant. Numerous such transgenic plants have been raised and summarized in the **Table 1** below.

TABLE 1: LIST OF TYRANSGENIC PLANTS OVER-EXPRESSIG PROTECTIVE BIOMOLECULES

Transgenic plant	Biomolecule accumulated	References
<i>Arabidopsis thaliana</i>	Proline	(Zhu <i>et al.</i> , 2012) ³²
<i>Oryza sativa</i>	Proline	(Yang <i>et al.</i> , 2012) ²⁹
<i>Nicotiana tabacum</i>	Proline	(Pan <i>et al.</i> , 2012) ²¹
<i>Brassica napus</i>	Proline	(Gomaa <i>et al.</i> , 2012) ⁵
<i>Brassica campestris</i>	Glycine Betaine	(Wang <i>et al.</i> , 2010) ²⁷
<i>Triticum aestivum</i>	Glycine Betaine	(Zhang <i>et al.</i> , 2010) ³¹
<i>Ipomea batatas</i>	Glycine Betaine	(Fan <i>et al.</i> , 2012) ³
<i>Xenopus laevis</i>	Trehalose	(Li <i>et al.</i> , 2009) ¹⁸
<i>Oryza sativa</i>	Trehalose	(Hossain <i>et al.</i> , 2010) ⁸
<i>Nicotiana tabacum</i>	Trehalose	(Yang <i>et al.</i> , 2010) ³⁰
<i>Hordeum vulgare</i>	Trehalose	(Ligaba <i>et al.</i> , 2011) ¹⁹
<i>Arabidopsis thaliana</i>	Trehalose	(Kang <i>et al.</i> , 2011) ¹¹
<i>Oryza sativa</i>	Trehalose	(Li <i>et al.</i> , 2011) ²⁰

CONCLUSION: Cold stress affects plants at all levels and the effects of cold stress are multiple and far reaching. This review thus focuses on the use of some of promising cryoprotetants in this regard. These biomolecules not only maintain the osmotic concentration of the cell sap but also protect and maintain the structure and function of various crucial enzymes and proteins besides preserving the integrity of various biomembranes.

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CONFLICT OF INTEREST: Corresponding author is the sole author hence no conflict of interest.

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