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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 plants [13] thus, the overall effects have been righty 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.

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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 crops [25].

Though, the primary site of cold injury and hence electrolyte leakage is plasma membrane [1] 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 enzymes [2].

It also protects the plant by maintaining the double stranded structure of genetic material *i.e.* DNA [16] and by up-regulating the anti-oxidative stress machinery [23].Thus, if exogenously supplied, proline can well mitigate the harmful effects of cold stress as reported by Kumar [14] 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 well [10].

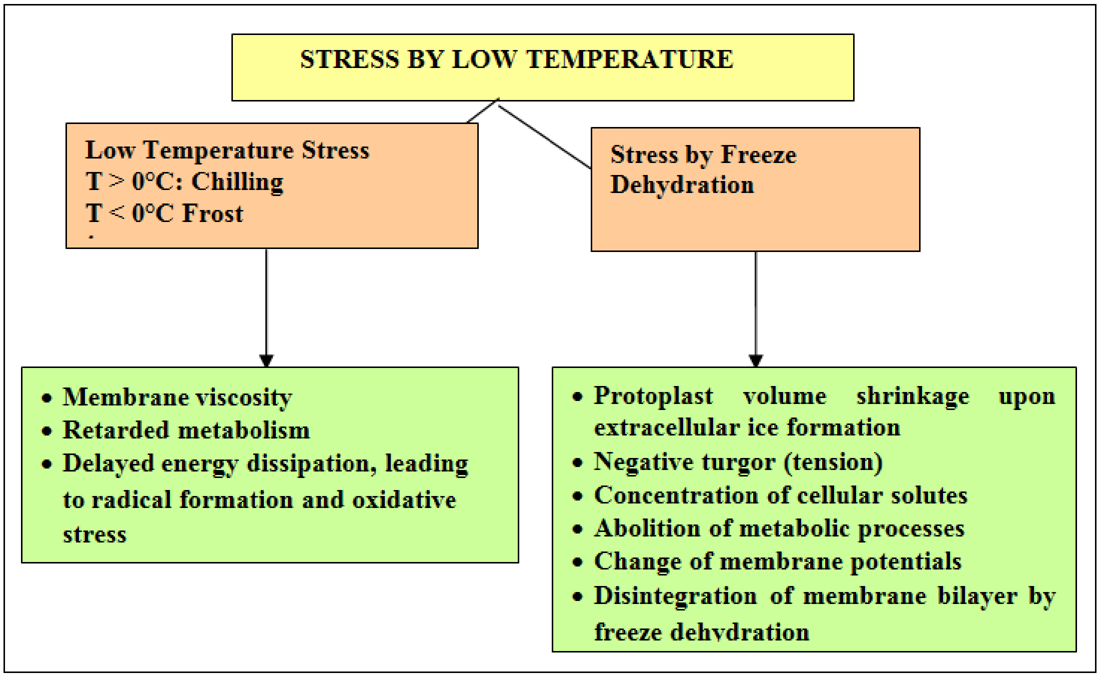

FIG. 1: THE COLD STRESS SYNDROME OF PLANTS

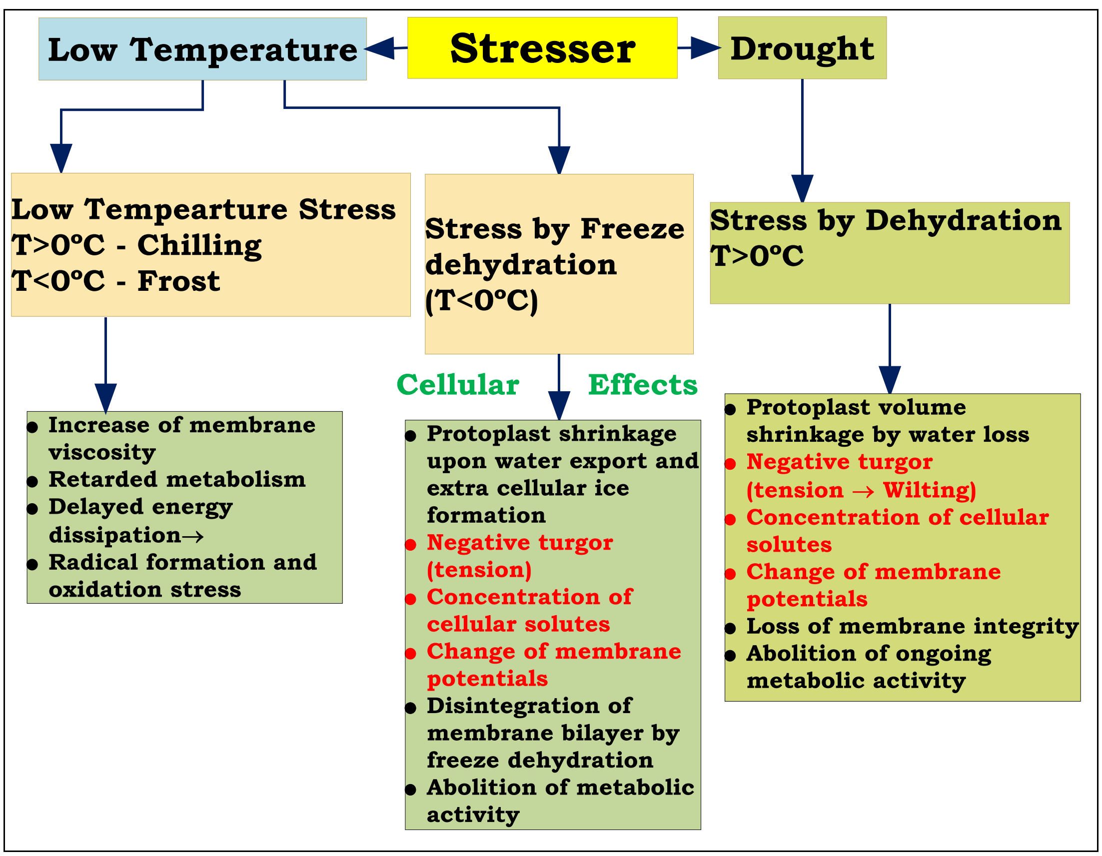

FIG. 2: STRAINS PRODUCED BY COLD AND DROUGHT IN PLANT TISSUES

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 machinery [4] by protecting the various components of PSII [15] and also as a molecular chaperone. Exogenously supplied GB improved the performance of tomato plants by [12]. Similarly, GB supplemented sweet pepper plants also performed better than untreated one under cold stress [28] which corroborated similar reportson wheat [31] and other grain crops [25].

Trehalose: Trehalose, an alpha linked disaccharide, has been proposed to be playing protective roles under various abiotic stresses including cold and freezing [9]. There are numerous reports of trehalose levels going up under low temperatures rice in Arabidopsis [26] and rice [20]. Thus, exogenously supplied trehalose thus can well protect not only cold stressed plants as proved in Arabidopsis [6] but also yeast [7] 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 conditions [24].

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