Emerging temperature stress protectants in plants

*Kalpna Bhandari

*Department of Botany, Panjab University, Chandigarh, India-160014.
*Corresponding author E-mail: kalpna.bhandari@gmail.com

Abstract Temperature stress is considered to be one of the most important stresses to which plants are exposed to under natural conditions. Numerous studies worldwide have been carried in this regard and the findings have proposed the exogenous application of various protective biomolecules for the amelioration of temperature stress. In additional to well established conventional osmoprotective biomolecules, now some non-conventional biomolecules are also being implicated in temperature tolerance.

Keywords: Temperature stress, plants, Abscisic acid, Jasmonates, Trehalose, Nitric oxide.

Introduction

Plants being sessile, cannot escape the various abiotic and biotic stresses under natural conditions. Temperature stress, in particular has been found to be having far-reaching effects on normal growth and development of plants. Thus, a no. of plant osmolytes and protective biomolecules such as proline have traditionally been used to alleviate the harmful effects of temperature stress. However, over the past few years, there has been a shift in the approach in this regard and many new biomolecules are also being employed for stress mitigation. So hereby, this article proposes the exogenous application of unconventional molecules such as Abscisic acid, Jasmonates , Trehalose and Nitric oxide for temperature stress mitigation.

Abscisic Acid (ABA)

ABA is an established plant stress messenger being capable of regulating water status. Thus, upon its exogenous supplementation, it has been found capable of conferring temperature stress tolerance as well in numerous plants (Table 1) when supplied alone (Bakht *et al.* 2006) or in collaboration with other biomolecules like salicylic acid (Szalai *et al.* 2011) thereby corroborating its role as an important alternative temperature stress protectant.

Jasmonates

Jasmonates, a class of plant hormones, have been proposed to play an important role in numerous plant processes. In association with salicylic acid, its exogenous application confers thermotolerance in Arabidopsis Clarke et al. (2004) and heat stress protection in grapes (Qin and Lin 2006). These reports were in corroboration with similar reports by Creelman and Mullet (1997) proposing the role of exogenously applied Methyl jasmonate in reducing membrane damage in heat stressed Arabidopsis.

Salicylic Acid (SA)

Salicylic acid is an important plant hormone playing diverse regulatory roles, especially ion biotic stress. However, it has recently been proposed to be protective against harmful effects of temperature stress as well, as proved by numerous studies worldwide (Larkindale and Huang 2004; Chakraborty and Tongden 2005). Exogenous application of SA provided heat tolerance to *Agrostis stolonifera* (Larkindale and Huang 2004), chickpea (Chakraborty and Tongden 2005). Aditionally, many reports of cold stress alleviation by SA have been reported in plants like bean (Senaratna et al. 2000),maize, cucumber and rice plants (Kang and Saltveit 2002), rice and wheat (Szalai et al. 2002,Tasgin et al. 2003),banana (Kang et al. 2003) etc.

Trehalose

Trehalose is a disaccharide with prominent role in drought, freezing and salinity stresses (Karim et al. 2007; Lopez et al. 2008). Sucrose being the major transport sugar in plants, trehalose doesn't accumulate in significant amounts and thus its role in plant metabolism couldn't be established earlier. Hence the discovery of its biosynthesis genes is also relatively new (Schleupmann and Paul 2009). Numerous studies have suggested the role of Trehalose in temperature stress protection (Table 1).

Table 1: Summary of exogenous supplementation of proposed biomolecules and the stress mitigated.

PLANT	EXOGENOUS BIOMOLECULE APPLIED	STRESS MITIGATED	REFERENCE
Alfalfa	ABA	Freezing	Mohapatra et al. 1988
Arabidopsis, Maize	ABA	Freezing	Xin and Li 1992
Wheat	ABA	Freezing	Dallaire et al.1994
Arabidopsis	ABA	Freezing	Mäntylä et al. 1995
Mustard	ABA	Heat	Chhabra et al. 2009
Chickpea	ABA	Heat	Kumar et al. 2012
Maize	ABA	Heat	Gong et al. 1998
Grapes	ABA	Heat	Abass and Rajasekhar 1993
Barley	ABA	Heat	Ivanov et al. 1992
Arabidopsis	JA	Heat	Clarke et al. 2004
Grapes	JA	Heat	Qin and Lin 2006
Rice, Wheat	SA	Cold	Szalai et al. 2002 Tasgin et al. 2003
Bean	SA	Cold	Senaratna et al. 2000
Banana	SA	Cold	Kang et al. 2003
Mustard	SA	Heat	Dat et al. 1998
Potato	SA	Heat	Lopez-Delgado et al. 1998
Creeping bentgrass	SA	Heat	Larkindale and Huang 2004
Chickpea	SA	Heat	Chakraborty and Tongden 2005
Arabidopsis	Trehalose	Cold	Hanhong et al. 2005
Barley	Trehalose	Cold	Muller et al. 2000
Rhodotorula Yeast	Trehalose	Cold	Li et al. 2008
Winter wheat	Trehalose	Cold	Luo et al. 2010
Faba beans	Trehalose	Heat	Gao et al. 2013

Conclusions

Thus, Abscisic acid, Jasmonates, Trehalose and Nitric oxide are potent osmoprotectantants and hence can be exploited as effective heat and cold stress protectants. However, these biomolecules don't accumulate in considerable amounts in higher plants, thus can be exogenously applied to the plants or additionally, plants may be genetically modified. Transgenics over-expressing the biosynthesis genes for these bomolecules were found to be tolerant to temperature stresses thereby further corroborating their role in temperature stress tolerance.

Acknowledgements

The technical support and access to e-journals provided by the Department of Botany, Panjab University, Chandigarh is highly acknowledged.

References

[1] A. G. Ivanov, M. I. Kitcheva, A. M. Christov, L. P. Popova, Effects of abscisic acid treatment on the thermostability of the photosynthetic apparatus in barley chloroplasts. Plant Physiol., 1992, 98: 1228-1232.

[2] B. Hanhong, H. Eliot, S. Richard, Exogenous trehalose promotes non-structural carbohydrate accumulation and induces chemical detoxification and stress response proteins in Arabidopsis thaliana grown in liquid culture. Plant Science, 2005, 168:1293–1301.

[3] B. Q. Li, Z. W. Zhou, S. P. Tian, Combined effects of endo-and exogenous trehalose on stress tolerance and biocontrol efficacy of two antagonistic yeasts. Biol. Control, 2008, 46:187-193.

[4] C. P. Qin, Y. S. Lin, Thermotolerance Related to Antioxidation Induced by Jasmonic Acid, Salicylic Acid and Heat Acclimation in Young Grape Plants. Masters Thesis, 2006,Shihezi University, Xinjiang, China.

[5] E. Mäntylä, V. Lang, T. Palva, Role of abscisic acid in drought-induced freezing tolerance, cold acclimation and accumulation of LT178 and RAB18 proteins in Arabidopsis thaliana. Plant Physiol., 1995, 107:141-148.

[6] E. Tasgin, O. Atici, B. Nalbantoglu, Effects of salicylic acid and cold on freezing tolerance in winter wheat leaves. Plant Growth Regul., 2003, 41:231–236

[7] G. Szalai, I. Tari, T. Janda, A. Pestenacz, E. Paldi, Effects of cold acclimation and salicylic acid on changes in ACC and MACC contents in maize during chilling. Biol. Plant., 2002, 43: 637-640.

[8] G. Szalai, M. Pál, T. Janda, Abscisic acid may alter the salicylic acid-related abiotic stress response in maize Acta Biol. Szeged., 2011, 55:155-157.

[9] G. Z. Kang, C. H. Wang, G. C. Sun, Z. X. Wang, Salicylic acid changes activities of H_2O_2-metabolizing enzymes and increases the chilling tolerance of banana seedlings Env. Exp. Bot., 2003, 50: 9-15.

[10] H. Lopez-Delgado, J. F. Dat, C. H. Foyer, I. M. Scott, Induction of thermotolerance in potato microplants by acetylsalicylic acid and H_2O_2 J. Exp. Bot., 1998, 49:713-720.

[11] H. M. Kang, M. E. Saltveit, Chilling tolerance of maize, cucumber and rice seedling leaves and roots are differentially affected by salicylic acid. Physiol. Plant., 2002 115:571-576.

[12] H. Schluepmann, M. Paul,Trehalose Metabolites in Arabidopsis—elusive, active and central. In The Arabidopsis Book. ASPB, 2009,pp: 1-17

[13] J. Bakht, A. Bano, P. Dominy, The role of abscisicacid and low temperature in chickpea (Cicer arietinum L.) cold tolerance. II. Effects on plasma membrane structure and function. J. Exp. Bot., 2006, 57: 3707-3715.

[14] J. F. Dat, H. Lopez-Delgado, C. H. Foyer, I. M. Scott, Parallel changes in H_2O_2 and catalase during thermotolerance induced by salicylic acid or heat acclimation in mustard seedlings. Plant Physiol., 1998 116:1351–1357

[15] J. Gao, N. Wang, S. S. Xu, Y. Li, Y. Wang, G. S. Wang, Exogenous application of trehalose induced H_2O_2 production and stomatal closure in Vicia faba. Biol. Plant., 2013, 57: 380- 384.

[16] J. Larkindale, B. Huang B, Thermotolerance and antioxidant systems in Agrostis stolonifera: involvement of salicylic acid, abscisic acid, calcium, hydrogen peroxide, and ethylene J. Plant Physiol., 2004,161: 405–413

[17] J. Muller, R. A. Aeschbacher, A. Wingler, T. Boller, A. Wiemken, Trehalose and trehalase in Arabidopsis. Plant Physiol., 2001 125:1086

[18] M. Abass, C. B. Rajshekhar, Abscisic acid accumulation in leaves and cultured cells during heat acclimation in grapes. Hortic. Sci., 1993, 28:50-52.

[19] M. Gong, Y. J. Li, S. Z. Chen, Abscisic acid-induced thermotolerance in maize seedlings is mediated by calcium and associated with antioxidant systems. J. Plant Physiol., 1998, 153, 488-496.

[20] M. L. Chhabra, A. Dhawan, N. Sangwan, K. Dhawan , D. Singh, Phtohormones induced amelioration of high temperature stress in Brassica juncea (L.) In Proceedings of 16th Australian Research Assembly on Brassicas, Ballarat, Australia, 2009, pp 10-14.

[21] M. Lopez, N. A. Tejera, C. Iribarne, C. Lluch, J. A. Herrera-Cervera, Trehalose and trehalase in root nodules of Medicago truncatula and Phaseolus vulgaris in response to salt stress. Physiol. Plant, 2008,134: 575-582

[22] R. A. Creelman, J. E. Mullet, Biosynthesis and action of jasmonates in plants.Ann. Rev. Plant Physiol. Plant Mol. Biol., 1997, 48: 355-381.

[23] S. Dallaire, M. Houde, Y. Gagn, H. S. Saini, S. Boileaul , N. Chevrier, F. Sarhan, ABA and Low Temperature Induce Freezing Tolerance via Distinct regulatory pathways in wheat. Plant Cell Physiol., 1994, 35: 1-9.

[24] S. Karim, H. Aronsson, H. Ericson, et al. Improved drought tolerance without undesired side effects in transgenic plants producing trehalose. Plant Mol. Biol., 2007, 64: 371-386.

[25] S. Kumar, N. Kaushal, H. Nayyar, P. Gaur , Abscisic acid induces heat tolerance in chickpea (Cicer arietinum L.) seedlings by facilitated accumulation of osmoprotectants. Acta Physiol. Plant., 2012 34: 1651-1658.

[26] S. M. Clarke, L. A. J. Mur, J. E. Wood, I. M. Scott, Salicylic acid dependent signalling promotes basal thermotolerance but is not essential for acquired thermotolerance in Arabidopsis thaliana. Plant J., 2004, 38: 432-447.

[27] S. S. Mohapatra, R. J. Poole, R. S. Dhindsa RS, Abscisic acid-regulated gene expression in relation to freezing tolerance in alfalfa. Plant Physiol., 1988, 87: 468-73.

[28] T. Janda, G. Szalai, I. Tari, E. Paldi, Hydroponic treatment with salicylic acid decreases the effect of chilling injury in maize (Zea mays L.) plants. Planta, 1999, 208:175-180.

[29] T. Senaratna, D. Touchell, E. Bunn, K. Dixon , Acetyl salicylic acid (aspirin) and salicylic acid induce multiple stress tolerance in bean and tomato plants. Plant Growth Regul., 2000, 30:157–161

[30] U. Chakraborty, C. Tongden , Evaluation of heat acclimation and salicylic acid treatments as potent inducers of thermotolerance in Cicer arietinum L.Curr. Sci., 2005; 89:384–389.

[31] Y. Luo, F. Li, G. P. Wang, X. H. Yang, Exogenously-supplied trehalose protects thylakoid membranes of winter wheat from heat-induced damage. Biol. Plant., 2010, 54: 495-501.

[32] Z. Xin, P. H. Li, Abscisic acid-induced chilling tolerance in maize suspension-cultured cells. Plant Physiol., 1992, 99: 707-711.