International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(3): 378-381
www.biochemjournal.com
Received: 23-12-2023
Accepted: 24-01-2024

Abhimanyu Patel
Guest Teacher,
Floriculture and landscaping
College of Horticulture and
Research Station Kunkuri
Jashpur MGUVV Raipur,
Chhattisgarh, India

Johnson Lakra
Assistant Professor,
Department of Fruit Sciences,
MGUVV, Sankra, Patan,
Durg, Chhattisgarh, India

Shashi Kant Ekka
Research Scholar, Department
of Horticulture, Fruit sciences,
SHUATS, Prayagraj, Uttar
Pradesh, India

Sunny Sharma
Assistant Professor, School of
Agriculture, Lovely
Professional University,
Phagwara, Punjab, India

Reena Kujur
Research Scholar, Department
of Biological Sciences,
SHUATS, Prayagraj, Uttar
Pradesh, India

Rajiv Kumar Kurrey
Lecturer, Department of
Agricultural processing and
Food engineering, College of
Horticulture and Research
Station, MGUVV, Kunkuri,
Jashpur, Chhattisgarh, India

Ravi Kumar
Post-Graduate, Department of
Horticulture, SHUATS,
Prayagraj, Uttar Pradesh,
India

Corresponding Author:
Abhimanyu Patel
Guest Teacher,
Floriculture and landscaping
College of Horticulture and
Research Station Kunkuri
Jashpur MGUVV Raipur,
Chhattisgarh, India

The role of organic solutes in the osmotic adjustment of chilling stressed vegetable and ornamental plants

Abhimanyu Patel, Johnson Lakra, Shashi Kant Ekka, Sunny Sharma, Reena Kujur, Rajiv Kumar Kurrey and Ravi Kumar

DOI: https://doi.org/10.33545/26174693.2024.v8.i3e.744

Abstract
Numerous abiotic stresses interrupt growth and development of plants and two important signals that cause to sever decrease the horticultural and crops yield are the heat and chilling stresses worldwide. Plants have various mechanisms to resist or avoid the stresses; one of these mechanisms is the biosynthesis of organic solutes. In this review, it explains about the effects of chilling (0-15 °C) stress on the horticultural crops that include ornamental and vegetable plants are discussed. The most important organic molecules to regulate water relations in plants are introduced. The organic solutes like proline and glycine that also are called osmo-protectants has been involved in stress tolerance.

Keywords: Abiotic stresses, osmo-protectants, proline, chilling stress

Introduction
Plants are subject to a variety of challenges throughout their optimal growth and development processes. These environmental factors negatively impact a plant's ability to grow, develop, and function in the end. Based on statistical data, it is possible that less than 10% of farms worldwide are free from significant environmental pressures. (Ashraf *et al*., 2007) [3]. Plants can respond to stress in two ways: through avoidance or through showing tolerance. Plants that possess avoidance strategies exhibit decreased autotrophic activity and enter a dormant state when faced with severe stress. In agricultural plant breeding, the goal is to create plants with avoidance strategies that lessen the consequences of stress, such as appropriate seasonal phenology. Enhancing plant resistance to abiotic stress is essential for improving production in situations when there is a water deficiency, salt, and cold stress. (Latef and Chaoxing, 2011) [2].

The intricate relationships between many phenomena (Such as chemistry, physiology, and molecules) and stress factors that impact plant growth and development are the cause of this. Although it is seasonal, cold stress is somewhat comparable to water deficit stress because plants experience a shortage of liquid water when freezing water generates concentrated solutes. (Ashraf *et al*., 2007) [3]. Among abiotic stressors, the effects of heat and cold are particularly important for agricultural goods' performance. Plants grow and develop to their full potential in an ideal temperature environment. Plant physiology, biochemistry, metabolism, and molecular statuses, however, will all alter when the surrounding temperature deviates from the ideal range.

Similar to other species, plant cells recognize and process signals through several cell surface receptors. (Upadhyaya *et al*., 2013) [10]. This might result in similar cellular adaptation reactions, such as the generation of appropriate osmolytes, the expression of stress proteins, and the activation of Reactive oxygen species (ROS) scavenging mechanisms. In general, a variety of strategies are used to protect plants from harm, such as their function in osmotic adjustment of cells, ROS detoxification, membrane integrity, and steady enzyme maintenance. These osmolytes also have the name "osmoprotectants" due to their ability to prevent dehydration of cellular components. Osmolytes include hydroxyproline betaine, choline O-sulfate, sucrose, trehalose, alanine betaine, glycine betaine, proline betaine, polyols, and proline. (Ashraf *et al*., 2007) [3]. As mentioned in Table 1, which presents different responses of ornamental plants to the chilling stress.

Table 1: Representing different responses of ornamental plants to various stress condition

S. No.	Test Plants	Stress type	Plant responses	Reference
1	*Lolium perenne* and *Festuca arundinacea*	Heat or cold stress	The three classes of Hsfs respond differently to high and low temperatures. HsfAs respond best to high temperatures, especially in HsfA2, while HsfBs respond best to both. HsfCs respond best to low temperatures. Specifically, heat shock protein (HSP), galactinol synthase (GOLS1), corbate peroxidase (APX), and inositol-3-phosphate synthase (IPS) were the genes that Hsfs targeted.	Wang *et al*. (2016) [12, 14]
2	Bermuda grass (*Cynodon dactylon* L. *Pers*.)	Cold stress	In both resistant and sensitive plants, exogenous ABA altered the expression of genes associated to ABA or cold, namely LEA, ABF1, and CBF1.	Huang *et al*. (2017) [8]
3	*Galanthus nivalis* L.	Chilling stress	Applying sucrose to G. nivalis leaves altered the ultrastructure and function of the photosynthetic apparatus, indicating that the chloroplasts' capacity to regulate their osmotic balance in response to cold stress.	Fediuk *et al*. (2017) [6]
4	*Dendranthema grandiflorum*	Low temperature	soluble sugar build-up followed by osmotic correction, which lowers cell water potential and increases water-holding capacity. Sugar serves as a carbon supply that enhances cold tolerance through physiological and metabolic processes.	Wang *et al*. (2018) [11]
5	*Artemisia judaica* L.	High temperature	To cope with the extreme cold and heat, plants are suppressed and their catalase, carbonic anhydrase, superoxide dismutase, and peroxidase are activated.	Abbas *et al*. (2017) [1]
6	*Hevea brasiliensis* Muell. Arg.	Cold stress	The main mechanism for surviving low temperature stress is the down-regulation of ethylene and auxin signaling, as well as the activation of ROS scavengers and the heat shock module.	Deng *et al*. (2018) [5]
7	*Kandelia obovata*	Cold stress	In order to deal with stressors, the member of primary HSP (heat shock protein) gene, KoHsp70, was found to be stress-inducible under cold stress.	Fei *et al*. (2015) [7]
8	*Dianthus spiculifolius*	Cold and drought stress	Identification of genes that are expressed in both the cold and drought stress response pathways that overlap and cross-talk.	Zhou *et al*. (2017) [16]

Chilling stress

One major environmental stressor that affects a plant's ability to develop and spread naturally is low temperature. Furthermore, cold temperatures change how plants absorb and take up water because they reduce hydraulic conductivity and lose stomata control. Additionally, cold stress reduces the capabilities and efficiencies of photosynthesis by altering pigment ratios, lowering chlorophyll fluorescence, and slowing down the formation of chloroplasts. (Latef and Chaoxing, 2011) [2].

Chilling stress is a significant environmental stressor that limits the plant performance. Chilling affects ROS, enzyme activity, and photosystem performance in different ways. In addition, it causes damage to leaves, male sterility, and a decrease in plant productivity. The decrease in ATP generation and the amount of phosphatidyl glycerol in the lipids of the thylakoid membrane can account for this result. Moreover, thylakoid membrane expansion or disintegration results in modifications to the chloroplast structure of leaves under cold stress, while there is no discernible change in leaf color. (Wang *et al*., 2016) [12, 14].

A plant that can withstand low or nonfreezing temperatures (0–15 °C) can grow in it without suffering any harm. According to Wang *et al*. (2016) [12, 14], the photosynthetic rate, ROS metabolism, and scavenging system of them are all closely related to the chilling-tolerant mechanism. In low temperatures, nearly all biological activity in plants is altered. The agricultural performance is adversely affected by these alterations brought on by cold stress.

Organic solutes

Osmolytes play a part in controlling cellular water relations and minimizing cell dehydration. One of the primary defense mechanisms of plants against stress may be the increasing accumulation of different suitable organic osmolytes. Compounds with a low molecular weight and good solubility are known as compatible osmolytes.

At high quantities in cells, these substances are usually not harmful (Ashraf *et al*., 2007) [3]. The production of organic osmolytes, including polyols, betaines, and other dipolar quaternary ammonium compounds, is thought to be a well-studied metabolic response of plant cells to hydro periodic stress. It appears that the buildup of cytoplasmic osmolytes will prevent damaging ionic power and lower cell water potential toward the environment.

The actual capacity of plants to tolerate salt, however, has never been fully established. It appears that both substances have a beneficial effect on the integrity of membranes and enzymes, and they also operate as mediators for osmotic adaptations in stressed plants (Ashraf *et al*., 2007) [3]. Stressed plants may be able to partially enhance its accumulation in their leaves by changing the expression of the genes encoding the enzymes responsible for biosynthesis. Still unknown, nevertheless, are the signals that influence gene expression (Burg and Ferraris, 2008) [4].

Proline

Stress-tolerant plants have larger concentrations of proline than stress-sensitive plants do. Proline's primary function extends beyond its position as an osmolyte; it also stabilizes different cell compartments (such as proteins and membranes), scavenges free radicals, and protects cells' redox potential from stressful situations (Ashraf *et al*., 2007) [3]. In 2011, Yuan *et al*., [15] treated the Freesia seedlings for six hours at 38°C, then grew the plants under heat stress conditions (30 °C) after recovering them for seventy-two hours at 22 °C. The pretreated seedlings exhibited increased amounts of proline and soluble carbohydrates, along with heat tolerance, according to their findings. As a defense against different biotic and abiotic adverse conditions, plants can build up free proline. When exposed to abiotic stressors, plants are thought to benefit from these modifications in their nitrogen metabolism.

Acidification of the cells brought on by stress may be lessened by proline levels, or more importantly, oxidative respiration, which provides the recovery energy. In comparison to normal circumstances, plants may maintain higher NAD(P)+ / NAD(P)H ratios while under stress. Additionally, the enhanced NADP+/NADPH ratio and improved oxidative pentose phosphate pathway activity may be aided by proline production.

In addition to directly scavenging ROS, proline functions indirectly to protect PSII in plants under drought stress. However, according to Upadhyaya *et al*., 2013 [10], there is no knowledge on the use of glycine betaine to directly scavenge ROS during abiotic stressors. Changes in the synthesis and oxidation of the amino acid by rising and decreasing respectively, are the first steps in the induction of proline buildup under stress.

Glycine betaine

N, N, N-trimethylglycine, also known as glycine betaine, is one of the most significant compatible solutes. It serves a variety of purposes as a preservative for plants exposed to extreme temperature, salt, and drought. Glycine betaine plays a crucial function in protecting membrane systems by reducing the levels of malondialdehyde (Roychoudhury and Banerjee, 2016) [9].

Glycine betaine protects cells against oxidative damage when they are under stress from the environment. In stressful conditions, glycine betaine, which mostly accumulates in the chloroplast, helps to preserve photosystem II efficiency. Furthermore, the administration of exogenous glycine betaine prevents structural damage caused by stress in organelles that generate reactive oxygen species, such mitochondria and chloroplasts (Upadhyaya *et al*., 2013) [10]. Additionally, spraying choline—the initial chemical in the glycine betaine production pathway—can encourage plants to accumulate glycine betaine (Roychoudhury and Banerjee, 2016) [9].

Glycine betaine applied exogenously can mitigate the adverse effects of heat on the growth of several crops. Additionally, two potato types have been encouraged to withstand low temperatures. Glycine betaine sprayed externally can improve both acclimated and non-acclimated strawberry (Fragaria x ananassa) plants' resistance to cold. In particular, applying it to strawberry plants without protection increased the plants' resistance to low temperatures by over 200%. According to these results, strawberry fields experiencing cold stress could benefit from the commercial use of glycine betaine (Ashraf *et al*., 2007) [3].

When glycine betaine is administered externally to plants, it penetrates tomato leaf surfaces and travels to different sections of the plant. The tissues of the sprayed plants had low levels of glycine betaine (>0.09 μmol g–1 FW), which helps protect them from freezing conditions. The cytosol contains the majority of the translocated glycine betaine content. This mechanism protects photosynthesis and increases freezing tolerance in glycine betaine-treated plants.

Soluble carbohydrates

Soluble sugars have a function in coordinating ROS signals and osmotic changes during environmental stressors. Sugars that dissolve in water are necessary for metabolism. They shield several metabolic pathways, such as oxidative pentose phosphate pathways, photosynthesis, and mitochondrial respiration, from ROS generation and scavenging mechanisms. Additionally, in plants exposed to osmotic stress, trehalose, a disaccharide sugar and signaling molecule, controls the metabolism of carbon and ABA (Upadhyaya *et al*., 2013) [10].

Conclusions

This review paper focuses on how chilling stress affects the quality and production of plants. Tolerance, one of a plant's defense systems, is explained. In contrast to avoidance measures like dormancy, which try to halt the activity, plants increase the activity of their metabolism. A multitude of hormonal, enzymatic, and molecular mechanisms work together to help plants adapt to various conditions. It might be argued that osmolytes, particularly proline, glycine, and betaine, play significant roles globally as nonenzymatic networks in a variety of plant groupings, including decorative and vegetative plants as well as cold-tolerant crops.

References

1. Abbas ZK, Saggu S, Rehman H, Al Thbiani A, Ansari AA. Ecological variations and role of heat shock protein in *Artemisia judaica* L. in response to temperature regimes of Tabuk, Saudi Arabia. Saudi Journal of Biological Sciences. 2017;24(6):1268-1273.
2. Abdel Latef AAH, Chaoxing H. Arbuscular mycorrhizal influence on growth, photosynthetic pigments, osmotic adjustment and oxidative stress in tomato plants subjected to low temperature stress. Acta Physiologiae Plantarum. 2011;33:1217-1225.
3. Ashraf MFMR, Foolad MR. Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environmental and Experimental Botany. 2007;59(2):206-216.
4. Burg MB, Ferraris JD. Intracellular organic osmolytes: function and regulation. Journal of Biological Chemistry. 2008;283(12):7309-7313.
5. Deng X, Wang J, Li Y, Wu S, Yang S, Chao J, *et al*. Comparative transcriptome analysis reveals phytohormone signalings, heat shock module and ROS scavenger mediate the cold-tolerance of rubber tree. Scientific Reports. 2018;8(1):4931.
6. Fediuk O, Bilyavska O, Zolotareva OK. Effects of sucrose on structure and functioning of photosynthetic apparatus of Galanthus nivalis L. leaves exposed to chilling stress. The Romanian Society for Cell Biology, Annals of RSCB. 2017;21(3):43-51.
7. Fei J, Wang YS, Zhou Q, Gu JD. Cloning and expression analysis of HSP70 gene from mangrove plant Kandelia obovata under cold stress. Ecotoxicology. 2015;24:1677-1685.
8. Huang X, Shi H, Hu Z, Liu A, Amombo E, Chen L, *et al*. ABA is involved in regulation of cold stress response in bermuda grass. Frontiers in Plant Science. 2017;8:1613.
9. Roychodhury A, Banerjee A. Endogenous glycine betaine accumulation mediates abiotic stress tolerance in plants. Tropical Plant Research. 2016;3:105-111.
10. Upadhyaya H, Sahoo L, Panda SK. Molecular physiology of osmotic stress in plants. In: Molecular stress physiology of plants. India: Springer India, 2013, 179-192.
11. Wang K, Bai ZY, Liang QY, Liu QL, Zhang L, Pan YZ, *et al*. Transcriptome analysis of chrysanthemum (Dendranthema grandiflorum) in response to low temperature stress. Bmc Genomics. 2018;19:1-19.
12. Wang LZ, Wang LM, Xiang HT, Luo Y, Li R, Li ZJ, *et al*. Relationship of photosynthetic efficiency and seed-setting rate in two contrasting rice cultivars under chilling stress. Photosynthetica. 2016;54(4):581-588.
13. Wang W, Vinocur B, Altman A. Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance. Planta. 2003;218:1-14.
14. Wang Y, Dai Y, Tao X, Wang JZ, Cheng HY, Yang H, *et al*. Heat shock factor genes of tall fescue and perennial ryegrass in response to temperature stress by

RNA-Seq analysis. Frontiers in Plant Science. 2016;6:1226.
15. Yuan Y, Qian H, Yu Y, Lian F, Tang D. Thermo tolerance and antioxidant response induced by heat acclimation in Freesia seedlings. Acta Physiologiae Plantarum. 2011;33:1001-1009.
16. Zhou A, Ma H, Liu E, Jiang T, Feng S, Gong S, *et al*. Transcriptome sequencing of *Dianthus spiculifolius* and analysis of the genes involved in responses to combined cold and drought stress. International Journal of Molecular Sciences. 2017;18(4):849.