Metabolic Adaptations in Plants During Abiotic Stress

Akula Ramakrishna

Sarvajeet Singh Gill

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Edited by
Akula Ramakrishna and Sarvajeet Singh Gill

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Dr. Ravishankar Gokare

This book is dedicated to Dr. Ravishankar Gokare, a renowned plant biotechnologist

and food biotechnologist of international repute.

Ravishankar Gokare was born in 1954 in Bangalore. He completed his BSc in 1972 at Bangalore University and further studies, MSc and PhD, in botany at the M.S. University of Baroda. He was a PhD student of Professor Atul R. Mehta, a renowned plant tissue culturist trained in the lab of Professor H.E. Street at Swansea, who was known as the Father of Modern Plant Tissue Culture. During his PhD he worked on metabolic regulation of secondary pathways in plants. He continued his postdoctoral work at CSIR Laboratory at Jammu-Tawi working on medicinal plants. He joined the Central Food Technological Research Institute, Mysore, in 1984 as Scientist B, where he had the fortune of working with India's most vibrant Algal Research Group, which was started by Dr. Wolfgang Becker of University of Tubingen in association with the eminent algal biotechnologist, Dr. L.V. Venkataraman. He rose to the level of Chief Scientist and Head of Plant Cell Biotechnology Department, a position he held for over 18 years.

Ravishankar initiated plant biotechnology and food biotechnology research at the Central Food Technological Research Institute (CFTRI), where he established a strong research group working on aspects of micro-propagation, conservation of biodiversity, bioactive metabolites, biosynthetic pathways in plants and microbes, metabolic regulation of secondary metabolites, post-harvest technologies for value addition to foods, and downstream processing of metabolites of food applications, such as food pigments, non-nutritive sweeteners, flavor molecules, etc. He was a pioneer in using elicitor technology to enhance metabolite yield in a standing crop of various plantation crops, which followed as an agronomic practice in various countries. Ravishankar is a plant conservation expert responsible for developing the tissue culture technology for a banana variety, Nanjangud Rasabale, which was facing the brink of extinction. Similarly, he was responsible for the development of technology for *Decalepis hamiltonii* (swallow root), a rich herb for adding value as a potent antioxidant source and an anticancer agent with the development of several recipes for health food application, including health drinks. The technology of swallow root was combined with the development of a mass production system through tissue culture methodology and the agronomic practice of cultivation, allowing for the conservation and sustainable utilization of this endangered herb. The benefits of this technology were transferred to the Soliga Tribes of BR Hills who are custodians of the germplasm, exemplifying the sharing of Intellectual Property Rights. Under Ravishankar's leadership, this was acclaimed as a star project of the Department of Science and Technology of the Government of India. In 1992, he received the Indian Science Congress Award for Young Scientist from the then Prime Minister of India for these contributions.

Ravishankar moved from metabolic regulation of secondary pathways to metabolic engineering in several systems. His group pioneered in the initiation of coffee biotechnology research under the Jai Vigyan project of the Government of India, sponsored by the Department of Biotechnology, which resulted in the development of transgenic coffee plants with lowered caffeine. The technology is useful for improvement of coffee plants for various traits. Various institutions including the Coffee Board, which collaborated under the All India Coordinated Project, benefited from the transformation system developed by his group. Ravishankar and his team worked on metabolic engineering of carotenoids in algae, with the production of astaxanthin in *Dunaliella* spp., which is otherwise known for β-carotene only. This was achieved by cloning the genes of astaxanthin pathway from *Haematococcus pluvialis* into *Dunaliella*. Similarly, the metabolic engineering of fatty acid production to produce gamma linolenic acid in soybean by the expression of the Delta 6 desaturase gene of Spirulina is another example of his innovative research. He is also well known for his studies on genomics in higher plants and microalgal systems. These studies earned him a coveted award in new biology given by the Indian Science Congress Association.

Ravishankar is known for his contributions with Dr. L.V. Venkatraman in commercializing spirulina technology in India. This is a model for several other biotechnologists in India wherein the involvement of industry was realized from the beginning of the scale-up to the transfer of technology, culminating in Asia's largest spirulina production unit in Nanjangud by Bhallarpur Industries Limited. This contribution was recognized by the Government of India with a National Technology Day Award in 2003. Presently, the Government of Karnataka has taken up spirulina supplementation for malnourished children, under the mid-day meal program. His group have developed several value-added spirulina food products for meeting the micronutrient deficiencies caused by a deficiency of iron, gamma linolenic acid, and vitamin A in staple diets. Ravishankar is a great mentor, too. He has guided over 25 PhD students as a supervisor and mentored over 160 graduate students, who have occupied high positions in India and abroad in academia, R&D labs, and in industry. He has been a popular teacher who is known for motivating young minds. His love for the academics and student-centric activities have been well recognized at his present role as Vice President of Life Sciences and Biotechnology at Bangalore's pioneering research and innovation driven institution, namely Dayananda Sagar Institutions/Dayananda Sagar University at Bengaluru.

His innovative ideas, hard work, and dedication is evidenced by the publication of 340 research and review papers in peer-reviewed journals and over 45 patents awarded in India and abroad. His work has received over 13,500 citations with an h-index of 57 at present. Ravishankar is a fellow of several academies in India and abroad. He plays an active role in the International Union of Food Science and Technology and the Institute of Food Technologists of the USA, who have recognized him with the honor of fellow. He is widely traveled and has given invited talks in many international symposia and seminars. He has been a visiting professor to universities in Japan, Taiwan, and Russia.

This book is dedicated to Dr. Ravishankar Gokare A, for mentoring a large number of students including one of the authors, Dr. Ramakrishna, and several researchers, who are contributing immensely to the field of plant biotechnology for food application. His simplicity, humble behavior, kindness to colleagues, and positive outlook is exemplary. We sincerely hope that he will continue to make contributions of global relevance and to nurture young generation of researchers to be global leaders.

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Foreword

Not every scientist in the world has the basic skills to write and compile a comprehensive book on a challenging research area like *Metabolic Adaptations in Plants During Abiotic Stress*. Dr. Akula Ramakrishna and Dr. Sarvajeet Singh Gill completed this work remarkably. They have teamed up to cover all the burning topics and mechanics pertaining to metabolic adaptations of plants during the adverse and stressed conditions related to polyamines, indoleamines, antioxidative systems, adaptations in seeds under arid conditions, the roles of osmoregulators, secondary metabolites and miRNAs, kinase signaling, the impact of ozone and flavonoids, mechanisms and operating pathways during stresses, photoinhibitory responses, genomic response, antioxidant isoenzymes, management of heavy metal stress, pesticide stress, ATPases in ion homeostasis, genetic engineering approaches for abiotic stress tolerance in plants for sustainable agriculture, and food security. All these topics make this book wonderful and highly useful to the scientific community.

This book is worth reading for every student and scientist doing active research in agriculture and abiotic studies. Some of you may be wondering why I am praising this book. This book matters because our climate is changing, and the plant kingdom is seriously affected, which plays a significant role in the sustainability of human life and the whole ecosystem on Earth. I strongly believe the content described here will be very useful for taking precautionary steps to sustain our agricultural system during upcoming adverse conditions.

This book provides a wide view of abiotic stress research materials to diversify each person's learning experiences. Students should cultivate new ideas by relating to the current research and knowledge described in simple and eloquent terms in each chapter. This thorough research should improve their knowledge and nurture their research productivity, as well stimulate incentives for further learning. This well-organized book provides an excellent opportunity for students, as well as for the whole scientific community.

I feel honored and privileged to have this opportunity to write a foreword to Dr. Ramakrishna and Dr. Gill's book. The challenges of abiotic stress in plant growth and development are evident, and the authors' dedication in this direction is appreciated. This is the area of future research that will help us all to thrive, along with plants.

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Acknowledgments

Our special thanks and heartiest gratitude to all the contributors of this volume, who have provided an ample treatise on the topic. We understand that the contributors are active scientists and have agreed to share their findings and perspectives with the readers, who will benefit from learning about the implications and applications of the subject matter of the book as an emerging area of science.

We are grateful to Alice Oven (Senior Editor), Jennifer Blaise (Senior Editorial Assistant), Lara Silva McDonnell (Senior Project Manager), and the team from Taylor & Francis for their help in bringing out the volume in an attractive manner.

Both of us are thankful to our families who encouraged us to take up this task and permitted us to take the time off from our relationships.

Dr. Ramakrishna is thankful to Monsanto Crop Breeding Center, Bengaluru, for their support and also thankful to his mentors Dr. G.A. Ravishankar and Dr. P. Giridhar for their guidance. Dr. Ramakrishna also extends thanks to the staff and students of the Plant Cell Biotechnology Department, CFTRI, Mysore, India. Dr. Gill also acknowledges the unconditional support and guidance of Professor (Dr.) Narendra Tuteja, ICGEB, New Delhi.

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Editors

Dr. Ramakrishna Akula is currently a scientist at Monsanto Breeding Station, Bangalore, India. Dr. Ramakrishna holds a master's degree from Sri Krishna Devaraya University, Anantapur, India. He started his research career in 2005 at the Department of Plant Cell Biotechnology, CFTRI, Mysuru, in the research group of Dr. G.A. Ravishankar. He is a Senior Research Fellow of CSIR, New Delhi. He obtained his PhD in biochemistry from University of Mysore, Mysuru, in the area of development of high frequency somatic embryogenesis and regulation of secondary metabolites in *Coffea canephora*. He worked extensively on the role of serotonin, melatonin, and calcium-mediated signaling in plants. He has made significant contributions to metabolic engineering of secondary metabolites from plants and abiotic stress in plants. He has worked in the area of tissue culture, in *vitro* production, and regulation of plant secondary metabolites from food value plants that include natural pigment caffeine, steviosides, anthocyanins, and carotenoids. He is the author of three books, 12 peer-reviewed publications, two reviews, and eight chapters in books. His books include *Serotonin and Melatonin: Their Functional Role in Plants, Food, Phytomedicine, and Human Health*, *Metabolic Adaptations in Plants During Abiotic Stress* (CRC Press, 2016) and *Neurotransmitters in Plants: Perspectives and Applications* (CRC Press, 2018). He is a member of the Society for Biotechnologists (India). He is a fellow of the Society for Applied Biotechnology, India (2012), and has received the Global Vegetable Research Excellence Award (2017), three global technology recognition awards, a Rapid Recognition Award, Test Master, Asia Veg R&D quarterly recognitions, and special recognition from the Monsanto company. He attended the Fifth International Symposium on Plant Neurobiology held in 2009 in Florence, Italy. He also attended the Technical Community of Monsanto (TCM) held in 2016, in St. Louis, Missouri.

Dr. Sarvajeet Singh Gill is currently working as assistant professor at the Centre for Biotechnology, Maharshi Dayanand University, Rohtak, Haryana, India. In 2001, Dr. Gill completed his MSc in Botany from Aligarh Muslim University, Aligarh, India, with Gold Medal. Soon after, Dr. Gill started his research career (M.Phil. and PhD, 2001–2008) in plant stress physiology and molecular biology at AMU. Dr. Gill has made significant contributions towards abiotic stress tolerance in crop plants. Dr. Gill's research includes abiotic stress tolerance in crop plants, reactive oxygen species signaling and antioxidant machinery, gene expression, helicases, crop improvement, transgenics, nitrogen and sulfur metabolism, and plant fungal symbiotic interactions. Together with Dr. Narendra Tuteja at the International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi, he worked on plant helicases for abiotic stress tolerance. He further explored the mechanism of stress tolerance by overexpressing PDH45 in tobacco and rice (*Plant Mol Biol* 82(1–2):1–22, 2013, and *PLoS One* 9(5):e98287, 2014). A novel function of plant MCM6 in salinity stress tolerance has also been reported that can will help to improve crop productivity at sub-optimal conditions (*Plant Mol Biol* 76(2011):19–34, 2014). Herbicide and salt stress tolerance (PDH45 + EPSPS) in plants has also been explored (*Front. Plant Sci.* 8:364, 2017). Dr. Gill helped to develop salinity-tolerant tobacco and rice plants, without affecting the overall yield. This research uncovers new pathways to plant abiotic stress tolerance and indicates the potential for improving crop production at sub-optimal conditions. A recipient of the INDIA Research Excellence & Citation Award 2017 from Clarivate Analytics (Web of Science), Sarvajeet Gill has edited several books with Springer, Wiley, Elsevier, CABI, and others, and has a number of research papers, review articles, and book chapters to his name.

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Section I

Abiotic Stress Management and Its Impact on Plants

1

Effects of Different Abiotic Stresses on Primary Metabolism

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Salinity Stress

General Considerations of Salt Stress as a Global Problem

Salt stress is one of the major abiotic stresses that seriously affect crop growth and yield. According to the Food and Agriculture Organization FAO (2009), there are at least 800 million hectares of land subjected to salinity in the world, accounting for as much as 6% of the world's total area. Although some of the salt-affected influences are the result of natural causes, the majority are derived from degraded cultivated agricultural land (Tang et al., 2014). It is estimated that 30% of the world's irrigated areas already suffer from salinity problems (UNESCO Water Portal, 2007). Each year, soil salinity increases worldwide, and it is predicted that it will cause a loss of up to 50% of the cultivatable land by 2050 (Henry et al., 2015). Expansion of agriculture to semi-arid and arid regions with the use of intensive irrigation will increase secondary salinization as a result of changes in the hydrologic balance of the soil between water applied (irrigation or rainfall) and water used by crops (transpiration). Moreover, the faster-than-predicted change in global climate (Intergovernmental Panel on Climate Change, 2007) and the different available scenarios for climate change suggest an increase in aridity for the semi-arid regions of the globe in the near future. Together with overpopulation this will lead to an overexploitation of water resources for agriculture purposes and increased constraints on plant growth and survival; this will affect the ability to realize crop yield potential (Chaves et al., 2009).

The United States Department of Agriculture (USDA) Salinity Laboratory defines a saline soil as having an electrical conductivity of the saturation extract (ECc) of 4 dS m^{-1} or more. ECc is the electrical conductivity of the saturated paste extract, that is, of the solution extracted from a soil sample after being mixed with sufficient water to produce a saturated paste. The most widely accepted definition of a saline soil has been adopted from FAO (1996) as one that has an ECc of 4 dS m^{-1} or more and soils with ECcs exceeding 15 dS m^{-1} are considered strongly saline. Traditionally, four levels of soil salinity based on saline irrigation water have been distinguished: low salinity is defined by electrical conductivity of less than 0.25 dS m^{-1}; medium salinity, 0.25–0.75 dS m^{-1}; high salinity, 0.75–2.25 dS m^{-1}; and very high salinity with an electrical conductivity exceeding 2.25 dS m^{-1} (US Salinity Laboratory Staff, 1954). The common cations associated with salinity are Na^+, Ca^{2+} and Mg^{2+}, while the common anions are Cl^-, SO_4^{2-} and HCO_3^- (FAO: Land and Water Division, 2013).

Saline stress in plants refers to the presence of neutral salts such as NaCl or Na_2SO_4 in soil, whereas alkaline stress is only

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related to the occurrence of alkaline salts: Na_2CO_3 or $NaHCO_3$. These conditions often co-occur in nature, with variable neutral to alkaline salt proportions according to the soil (Paz et al., 2014). Since Na^+ in particular causes deterioration of the physical structure of soil and along with Cl^- is toxic to plants, these are considered the most important ions. Historically soils were classified as saline, sodic or saline-sodic based on the total concentration of salt and the ratio of Na^+ to Ca^{2+} and Mg^{2+} in the saturated extract of the soil (Yadav et al., 2011).

According to the incapacity to grow on high salt medium, plants have also been classified as glycophytes or halophytes. Most plants are glycophytes and cannot tolerate salt stress and in a large proportion of crops cannot tolerate Na^+ concentrations at 50 mM or higher (Tang et al., 2014). The deleterious effects of salinity on plant growth are associated with: (1) low osmotic potential of soil solution (water stress), (2) nutritional imbalance, (3) specific ion effect (salt stress) or (4) a combination of these factors (Parvaiz and Satyawati, 2008). Early plant responses to water and salt stress have been considered mostly identical; drought and salinity share a physiological water deficit that affects, more or less intensely, all plant organs (Munns, 2002). However, under prolonged salt stress plants respond in addition to dehydration to hyper-ionic and hyper-osmotic stress (Fricke et al., 2006). Na^+ and Cl^- are taken up and, increasingly, displace mineral nutrients such as K^+, Ca^{2+} and nitrate (Campestre et al., 2016). Although accumulation of Na^+ and Cl^- causes osmotic and water potential adjustment of cells, it increases the risk of long-term ion toxicity. If Na^+ and Cl^- are not compartmentalized appropriately, exported or secreted, leaf tissue water deficit per se can be triggered not only by low soil water content but also by high vapor pressure deficit of the atmosphere (Chaves et al., 2016; Paz et al., 2014). Photosynthesis, together with cell growth, is among the primary processes to be affected by drought (Chaves, 1991) or by salinity (Munns et al., 2006). The effects can be direct, as the decreased CO_2 availability caused by diffusion limitations through the stomata and the mesophyll, and alterations of photosynthetic metabolism, or they can arise as secondary effects, namely oxidative stress. The latter are mostly present under multiple stress conditions and can seriously affect leaf photosynthetic machinery (Chaves et al., 2009).

In recent years, much attention has been devoted to the involvement of polyamines (PAs) as second messengers in the context of a variety of environmental stresses (Marina et al., 2008). These low-molecular-weight, aliphatic nitrogenous compounds, which are protonated at physiological pH, were originally thought to bind to anionic macromolecules, including proteins and nucleic acids, and thus to perform a structural role (Gárriz et al., 2003). The three commonest plant PAs, namely putrescine (Put), spermidine (Spd) and spermine (Spm), are now known; they protect salinity-stressed plants by aiding the accumulation of sugars, proline (Pro) and other osmolytes, and adjusting ion channels to maintain the plant's internal K^+ and Na^+ balance. They also serve to increase the activity of a range of antioxidant enzymes, thereby improving the plant's ability to control oxidative stress. The involvement of PAs in the response of higher plants to salinity stress has been widely reported (Zheng et al., 2016) and deserves to be mentioned, however, we focus in this chapter on plant primary metabolism and how different abiotic stresses affect it.

In recent years, tremendous advances have been achieved in salt stress studies. Plant breeders have fostered some salt-tolerant lines of crops by conventional breeding; moreover, a transgenic approach is employed to improve crop salt tolerance and a number of transgenic lines have been found to be effective under control conditions. Metabolomics is becoming a tool to understand the cellular mechanism of abiotic stress and acts as a viable option for the biotechnological improvement of halophytes (Tang et al., 2014). Nevertheless, the salt tolerance trait is a multigenic property and is related to physiological, biochemical and molecular processes, so genetic engineering to produce salt-tolerant crops is limited seriously in nature (Zhu, 2003). More energy, material and financial resources are needed to invest in research. Only in this way can the mechanisms and principles be discovered and corresponding solutions be proposed.

Growth and Crop Production under Salt Stress Conditions

The effect of salt on plant establishment has been assessed in maize, sorghum, rice, wheat and soybean. Osmotic stress resulting from drought or salinized soils can be disastrous for crop development (Westgate and Boyer, 1985). Both stresses have a common but not exclusive osmotic component. Salinity generates an immediate osmotic stress followed by later ion toxicity after continued exposure (Carillo et al., 2011). During stress conditions, plants need to maintain internal water potential below that of soil and maintain turgor and water uptake for growing. This requires an increase in osmosis, by uptake of soil solutes, synthesis of metabolic solutes or accommodation of the ionic balance in the vacuoles (Parvaiz and Satyawati, 2008). Growing or surviving in a saline soil imposes some costs: the cost of excluding salt by intracellular compartmentalization and of excreting it through salt glands. This cost, however, is relatively small in relation to that needed to synthesize organic solutes for osmotic adjustment (Munns, 2002).

As was mentioned before, plants have been classified as glycophytes or halophytes. Most plants are glycophytes and cannot tolerate salt stress (Parvaiz and Satyawati, 2008). Nevertheless, important differences exist in salt tolerance between species. In most plants, higher levels of the activity of antioxidant enzymes are considered as salt tolerance mechanisms (Ashraf, 2009; Zhang et al., 2014). Indeed, previous studies have shown that within the same species, salt-tolerant cultivars generally have higher constitutive or enhanced antioxidant enzyme activity under salt stress when compared with salt-sensitive cultivars. This has been demonstrated in numerous plant species such as cotton (*Gossypium herbaceum*), rice and pea. Moreover, the response of plant antioxidant enzymes to salinity has been shown to vary among plant species, tissues and subcellular localizations (Mittova et al., 2003). Dramatic variances are found between plant species production in saline versus control conditions over a prolonged period of time. For example, after some time in 200 mM NaCl, a salt-tolerant species such as sugar beet (*Beta vulgaris*) might have a reduction of only 20% in dry weight, a moderately tolerant species such as cotton might have a 60% reduction, and a sensitive species such as soybean might be dead (Greenway and Munns, 1980). In very salt-sensitive species, salt-specific effects can become visible after several days at high salinities. If the salinity is high, and if the plant has a poor ability to exclude NaCl, marked injury in older leaves might occur within days, as found for white lupin (*Lupinus albus*) once the salinity increased above 100 mM NaCl (Munns, 1988). *Medicago sativa* plants showed after 4 and 6 weeks of salt treatment a biomass reduction of about 40% and 50% with 150 mM NaCl, respectively (López-Gómez et al., 2014). At first the growth reduction is quickly apparent, and is due to the salt outside the roots. It is essentially a water stress or osmotic phase, for which there is surprisingly little genotypic variation (Munns, 2002). The growth reduction is presumably regulated by hormonal signals coming from the roots. Then, there is a second phase of growth reduction, which takes time to develop, and results from internal injury. This internal injury is due to Na^+ or Cl^- (or both) accumulating in transpiring leaves to excessive levels, exceeding the ability of the cells to compartmentalize these ions in the vacuole. Ions then build up rapidly in the cytoplasm and inhibit enzyme activity or they build up in the cell walls and dehydrate the cell (Flowers and Yeo, 1986). This process inhibits the growth of the younger leaves by reducing the supply of carbohydrates to the growing cells (Munns, 2002).

Evidence indicates that plants have two phases of growing response that have been shown clearly, for example, for maize and wheat cultivars. Two maize cultivars with two-fold differences in rates of Na^+ accumulation in leaves had the same growth reduction for 15 days in 80 mM NaCl. Furthermore, another two maize cultivars, again with two-fold differences in Na^+ accumulation, had the same growth reduction for 4 weeks in 100 mM NaCl, and it was not until 8 weeks of salinity that a growth difference was clearly observed (Munns, 2002).

Differences are evident between the phenotype given by salt-stressed maize plants versus control irrigated only with nutritive solution (Henry et al., 2015). Similar results were found in wheat (Munns et al., 1995). Maize plants are most susceptible during a period of 2 weeks around the time of silking, and kernel abortion is the limiting factor for yield (Boyer, 2010). Recent studies identify events as early as 1 day after pollination to be critical for determining whether the embryo will abort (Chaves et al., 2003). With rice, also, a clear distinction has been made between the initial effects of salinity, which are recoverable, and the long-term effects that result from the accumulation of salt in the expanded leaves (Yeo et al., 1991).

In general, in the first few seconds or minutes of salt stress exposure, plant cells lose water and shrink. Then, cells regain their original volume but cell elongation rates are reduced, leading to lower rates of leaf and root growth. Over a number of days, changes in cell elongation and cell division lead to slower leaf appearance and smaller final size, and leaf growth is usually more affected than root growth (Munns, 2002). Root ionic status does not increase with time, as in leaves, and they often have a lower Na^+ and Cl^- concentration than the external solution, which rarely happens in leaves. For example, in wheat growing in 150 mM NaCl, Na^+ in the roots was only 20–40 mM (Gorham et al., 1990). In plants with high salt uptake rates, the oldest leaf may start to show symptoms of injury. After months, differences between plants with high and low salt uptake rates become very apparent, with a large amount of leaf injury and complete death in some cases if the salinity level is high enough (Munns, 2002).

In maize, kernel abortion induced by osmotic stress correlates with reduced evapotranspiration and photosynthesis (Setter and Flannigan, 2001). Along with impaired photosynthesis in source leaves comes a reduction of seed sink strength. Abortion caused by osmotic stress correlates with depleted sucrose and reduced sugar levels, reduced sucrose degrading enzyme activity and transcript levels, and depletion of starch in the kernels (Henry et al., 2015). These events occur in a short period of time around pollination and can be partially prevented by stem sucrose feeding (Boyer, 2010). As a result of impaired photosynthesis and sink strength, sugar allocation to the reproductive organs is disrupted and the young embryo rapidly starves and aborts. Sugars not only serve as a source of carbon units and metabolic energy but also function as signaling molecules reporting carbon status within the cell (León and Sheen, 2003; Henry et al., 2015).

Seedling stage is the more vulnerable phase of durum wheat (*Triticum durum*) growth under salinity (Carillo et al., 2008). This species is more sensitive to salinity than bread wheat (*Triticum aestivum*) and poor yields on saline soil are partly due to the poor ability of durum wheat to exclude sodium (Annunziata et al., 2017). In particular, salinity greatly increases the levels of proline and glycine betaine (GB) in durum wheat (Munns, 2002; Carillo et al., 2008), as in other Poaceae. In many halophytes, leaf concentration of Pro, GB or both contributes to the osmotic pressure in the cell as a whole. In glycophytes, proline and GB have lower concentrations but, being partitioned exclusively to the cytoplasm, which makes up about 10% of the volume of the cell, they are able to determine significant osmotic pressure and balance the vacuolar osmotic potential (Annunziata et al., 2017).

The effect of salinity on the germination, vegetative growth and yield of cotton has also been reported (Ahmads et al., 2002; Guo et al., 2012). Cotton is classified as a salt-tolerant crop, but this tolerance is actually limited and varies according to the growth and developmental stages of the plant. Breeders have sought to make cotton more tolerant to salt through various methods, including traditional plant breeding and biotechnological approaches such as creating transgenic cotton (Chen et al., 2016). The growth rates of cotton plant roots and leaves decrease with increasing salt concentration, which may be a result of osmotic injury or specific ion toxicity (Meloni et al., 2001). Salt stress significantly reduces the growth rates in surface area, volume, average diameter of the cotton roots, and dry weights of roots and leaves (Zhang et al., 2014). This is accompanied by strong changes in carbohydrate metabolism owing to severe impairments in the photosynthetic and respiration apparatus (Chen et al., 2016).

On the other hand, legumes are classified as salt-sensitive crop species and their productivity is particularly affected because nodular nitrogenase activity markedly decreases upon exposure to mild saline conditions (Läuchli, 1984; López-Gómez et al., 2014). Salinity stress reduces seed germination, seedling growth, nodulation, biomass accumulation and seed yield (Essa, 2002). López-Gómez et al. (2014) have studied *M. sativa* and determined that nitrogenase activity is strongly inhibited by 150 mM NaCl 2 weeks after treatment initiation. The glycophyte *Lotus tenuis* (Waldst and Kit, syn. *L. glaber*; Kirkbride, 2006) is the best-adapted legume forage in the lowlands of the Buenos Aires Province (the most important cattle production region in Argentina) and is also affected by salt stress. The negative effect of NaCl on root length of *L. tenuis* is in agreement with previous results (Echeverria et al., 2008) along with important levels of growth inhibition on its shoots that significantly decrease persistence and yield (Mazzanti et al., 1986; Paz et al., 2014). Singleton and Bohlool (1983) showed that nodule function was relatively more resistant to salt stress than plant growth. High soybean yields require large amounts of nitrogen (N); the least expensive source of N for soybean is biological fixation of atmospheric N_2 by the symbiotic association between plant and soil bacteria belonging mainly to the genera *Bradyrhizobium* and *Sinorhizobium*, which are collectively called soybean rhizobia. Rhizobia infect the roots of legumes and induce formation of nodules, where nitrogen fixation takes place (Baghel et al., 2016). Similarly to the nitrogenase activity, nodule dry weight was also reduced by salt treatments particularly in the case of *M. sativa* in which 35% and 50% of reduction was obtained by 100 and 150 mM NaCl after 2 weeks (López-Gómez et al., 2014).

Owing to the high oil and protein content in its seeds, soybean is an important economic dicot crop and the demand for it is increasing continuously. However, as a salt-sensitive species, the growth and development are severely affected by salt stress. Exploiting resistant varieties and improving salt tolerance of soybean, therefore, became the goal of many researchers (Chen et al., 2011). In mature seedlings of cultivated soybean (*Glycine max*), the water potential was reduced 11.2 times and the relative water content dropped to 64.2% under 300 mM treatment. In addition, all the plants under this stress displayed symptoms of water loss and 30% died after the stress. For young seedlings the accumulation of Pro increased rapidly when the concentration of the NaCl reached 100 mM or higher. Under 300 mM, the contents of the Pro reached 34.4 times. Previous studies on the synthesis and degradation of Pro have proved a close relationship between Pro and salt resistance. GB was another important metabolite playing an important role in salt resistance and its behavior was similar to Pro (Wu et al., 2014). The Pro content in the cotyledons of the 4-day-old germinating soybeans increased in the plants subjected to NaCl stress as well as the gamma-aminobutyric acid (GABA) content (Yin et al., 2015).

Plant Chemical and Physical Response to Salt Stress

An efficient response to the environment is particularly important for plants, as sessile organisms. This means an ability of cells to quickly sense the surrounding environmental signals. Systemic signals generated by the tissue exposed to abiotic and biotic stress act in the co-ordination and execution of plant stress responses in terms of metabolic and developmental adjustments (Chaves et al., 2003). Under salt and drought, these responses are triggered by primary osmotic stress signals, which have an impact on both the source of carbohydrate (photosynthesis) and the mobilization/utilization of carbohydrate reserves (sink strength), or by secondary signal metabolites that generally increase or decrease in a transient mode. The latter include hormones (e.g. abscisic acid (ABA), ethylene, cytokinins), reactive oxygen species (ROS) and intracellular second messengers, e.g. phospholipids, sugars, etc. (Chaves et al., 2003). Salt stress signaling consists of ionic and osmotic detoxification and signaling to coordinate cell division and enzyme expansion. Several salt-responsive signaling pathways, such as salt overly sensitive (SOS), ABA, Ca^{2+} signal transduction, protein kinase, phospholipid, ethylene and jasmonate acid (JA) induced signaling pathways, have been predicted (Zhang et al., 2012).

Stomata close in response to leaf turgor decline, high vapor pressure deficit in the atmosphere (Chaves et al., 2009) and early physiological events such as root-generated chemical signals. A close relationship is usually found between stomata conductance (Gs) and net CO_2 assimilation (A_N) (Flexas et al., 2004); photosynthesis rate is affected by salt stress directly due to CO_2 deficiency and Rubisco (RuBP) activity, and indirectly by reduced chlorophyll and total carotenoid content (Tang et al., 2014).

Since roots are the site of perception of salt in the environment, their responses and adaptive behavior form the first line of defense against stress damage (Ji et al., 2013). High concentrations of NaCl outside the roots reduce the water potential and make it more difficult for the root to extract water (Zhang et al., 2014). Sodium exclusion by root cells is the primary protecting response in plants that delays the toxic effects of high cytoplasmic Na^+. The comparison of unidirectional Na^+ uptake fluxes and the rates of net accumulation of Na^+ in roots indicate that the vast majority of the Na^+ taken up into the root symplast is extruded back to the apoplast and soil solution (Ji et al., 2013). Proper regulation of ion flux is necessary for cells to keep the concentrations of toxic ions low and to accumulate essential ions. Plant cells employ primary active transport, mediated by H^+-ATPases (Yokoi et al., 2002) that create a proton-motive force that drives the transport of all other ions and metabolites; and a secondary transport, mediated by channels and co-transporters, to maintain characteristically high concentrations of K^+ and low concentrations of Na^+ in the cytosol (Parvaiz and Satyawati, 2008).

The cytoplasm also accumulates low-molecular-mass compounds commonly called compatible solutes that do not interfere with normal biochemical reactions; rather, they replace water in biochemical reactions. While some compatible osmolytes are essential elemental ions (such as K^+) (Xiong et al., 2002), the majority are organic solutes (Zhu, 2003). However, the solutes that accumulate vary with the organism and even between plant species. A major category of organic osmotic solutes consists of simple sugars (mainly fructose and glucose), sugar alcohols (glycerol and methylated inositols) and complex sugars (trehalose, raffinose and fructans). Carbohydrates (glucose, fructose, sucrose, fructans) and starch accumulate under salt stress, playing a leading role in osmoprotection, osmotic adjustment, carbon storage and radical scavenging (Parvaiz and Satyawati, 2008). Others include quaternary amino acid derivatives (proline, glycine betaine, β-alanine betaine, proline betaine, tertiary amines 1,4,5,6-tetrahydro-2-methyl-4-carboxyl pyrimidine) and sulfonium compounds (choline O-sulfate, dimethyl sulfonium propionate) (Bohnert and Jensen, 1996; Yokoi et al., 2002).

Under mild stress, a small decline in stomata conductance may have protective effects against stress, by allowing plants to save water and improving plant water-use efficiency. The result of closing stomata is the reduction of CO_2 diffusion. There is an increasing body of evidence that shows g_m (internal leaf conductance to CO_2 diffusion) decreases in response to drought and salinity (Flexas et al., 2004). These changes in mesophyll conductance may be linked to physical alterations in the structure of the intercellular spaces due to leaf shrinkage or to alterations in the biochemistry (bicarbonate to CO_2 conversion) and/or membrane permeability (aquaporins) (Chaves et al., 2009).

The cell cortex is a specialized layer of the cytoplasm underlying the plasma-membrane that is composed of a network of microtubules and actin filaments. Cortical microtubules are highly dynamic and remodeled by numerous stimuli. Salt stress induces dynamic cytoskeletal changes, with initial depolymerization of microtubules at the onset of stress followed by repolymerization. Both depolymerization and reorganization of the cortical microtubules are important for the plant's ability to withstand salt stress (Ji et al., 2013).

Changes in leaf biochemistry that result in down-regulation of the photosynthetic metabolism may occur in response to lowered carbon substrate under prolonged stresses (Flexas et al., 2006). A deactivation of the carboxylating enzyme RuBP by low intercellular CO_2 has been observed along with other important photosynthetic proteins that are down-regulated by different mechanisms (carbonylation, phosphorylation/dephosphorylation and redox changes in thiol groups). These salt-induced alterations may induce great disturbances in photochemical activity, decreasing the growth and increasing salt plant sensitivity (Henry et al., 2015; Silveira and Carvalho, 2016). There is a large amount of data on initial RuBP activity and only one study in which nitrate reductase activity was followed concomitantly with Gs during a drought cycle. Even so, it seems clear that both enzymes share a common pattern on regulation with decreasing Gs. The fact that initial RuBP activity remains unaffected from maximum Gs down to 0.1 mol H_2O m^{-2} s^{-2} implies that within this range, photosynthesis is not impaired by the carboxylation capacity (Flexas et al., 2004). Early biochemical effects that involve alterations in photophosphorylation (a decrease in the amount of ATP leading to a decreased regeneration of Rubisco) have also been described (Tezara et al., 1999) and seem to be dependent on species showing different thresholds for metabolic down-regulation (Lawlor and Cornic, 2002).

Under salt stress, metabolic limitations of photosynthesis resulting from increased concentrations of Na^+ and Cl^{-2} in the leaf tissue (in general above 250 mM) do occur (Munns et al., 2006). As previously pointed out, the fast changes in gene expression following stress imposition that have been observed suggest that alterations in metabolism start very early. Although its role is not totally clear yet, photorespiration may also be involved in protecting the photosynthetic apparatus against light damage as suggested by its increase under drought observed in several species. Photorespiratory-produced hydroxide peroxide (H_2O_2) may also be responsible for signaling and acclimation under restricted CO_2 availability (Noctor et al., 2002). Several lines of evidence suggest that stomatal closure in moderately salt-stressed leaves leads to enhanced rates of photorespiration. The following parameters, all indicative of higher rates of photorespiration, have been shown to increase: the CO_2 compensation point, the light to dark ratio of CO_2 production, the stimulation of photosynthesis by lowering the O_2 concentration, the activity of glycolate oxidase and the formation of photorespiratory metabolites, such as glycine, serine and glycolate. The maintenance of considerable rates of electron transport in CO_2-free air also indicates a significant occurrence of photorespiration in salt-stressed leaves. In addition to sustained rates of electron transport due to photorespiration, the formation of zeaxanthin (one of the most common carotenoid alcohols found in nature) also mitigates against photo inhibitory damage, although this protection by zeaxanthin is not complete in high light (Wingler et al., 2000).

Salt-tolerant plants can not only regulate ion and water movements more efficiently but should also have a better antioxidant system for effective removal of ROS (Noctor et al., 2002). Molecular oxygen in its ground state, triplet oxygen, is essential to life on earth. It is a relatively stable molecule that does not directly cause damage to living cells. However, when triplet oxygen receives extra energy or electrons, it generates a variety of ROS that will cause oxidative damage to various components of living cells including lipids, proteins and nucleic acids (Abogadallah, 2010). Salt stress causes excessive generation of ROS: singlet oxygen ($^1O2$), hydrogen peroxide (H_2O_2), superoxide anions (O^{-2}) and hydroxyl radicals (OH•). To mitigate the oxidative damage initiated by ROS formed under salt stress, plants possess a complex antioxidant system, including non-enzymatic antioxidants such as ascorbic acid, glutathione, tocopherols and carotenoids; antioxidant enzymes such as superoxide dismutase, catalase, glutathione peroxidase and enzymes of the so-called ascorbate-glutathione cycle, including ascorbate peroxidase and glutathione reductase (Zhang et al., 2014). Plants produce ROS under normal conditions essentially from photosynthesis, photorespiration and respiration. The most common ROS generated under normal conditions are O^{-2} and H_2O_2 perhaps as a result of electron leakage from the photosynthetic and respiratory electron transport chains to oxygen. Another source of ROS (H_2O_2) is photorespiration resulting from the oxygenase activity of RuBP. Rates of photorespiration are basically controlled by the ratio of [CO_2] to [O_2] and temperature. In C_3 plants, photorespiration constitutes about 20%–30% of photosynthesis under the current atmospheric conditions at 25°C. In contrast, C_4 plants show lower rates of photorespiration (3.5%–6% of photosynthesis) under various environmental conditions due to their CO_2 concentrating mechanism. The role of ROS detoxification under salt stress may have resulted at least in part from (1) the technical inability to determine the major sources(s) of ROS under salt stress and therefore the appropriate antioxidant enzyme required and (2) the expectation that ROS scavenging enzymes, particularly catalases and peroxidases, perform similar functions (Abogadallah, 2010).

Salinity can affect growth in a number of ways. The first phase of the growth response is due to the osmotic effect of the salt in the soil solution and produces a suite of effects identical to those of water stress caused by drought. Later, there may be an additional effect on growth; if excessive amounts of salt enter the plant they will eventually rise to toxic levels in the older transpiring leaves, causing premature senescence. This will reduce the amount of assimilate that the plant can produce, and a reduction in assimilate transported to the growing tissues may further limit growth. This is the second phase of the growth response and is the phase that clearly separates species and genotypes that differ in the ability to tolerate saline soil (Munns, 2002). In summary, in order to guarantee survival under such detrimental circumstances, plants have evolved a series of biochemical and molecular processes to acclimatize themselves to the environment (Yan et al., 2013). The specific biochemical strategy contains: (1) ion regulation and compartmentalization, (2) induced biosynthesis of compatible solutes, (3) induction of antioxidant enzymes, (4) induction of plant hormones and (5) changes in photosynthetic pathway. The molecular mechanism includes: (1) the salt overly sensitive (SOS) pathway for ion homeostasis, (2) the protein kinase pathway for stress signaling, (3) the phytohormone signaling pathway under high salt stress and (4) the associated genes encoding salt-stress proteins, such as genes for photosynthetic enzymes, synthesis of compatible solutes, vacuolar-sequestering enzymes and for radical-scavenging enzymes (Tang et al., 2014).

The accumulated knowledge on physiological, cellular and molecular responses of plants to drought and salinity, including the signaling events occurring under both stresses, is already permitting great progress in crop management and breeding (Chaves et al., 2009). Some improvement in plant stress tolerance has been achieved by introducing stress-inducible genes into some model plants. To further understand the complexity of plant response to drought and salt, including the effects on photosynthesis, is important to strengthen multilevel genomics and physiological studies, covering different intensity and timing of imposition of the stresses in genotypes with different sensitivity to stress.

Cold Stress

Effect of Cold Stress on Primary Plant Metabolism

Climatic changes affect the normal performance of the plant. Low temperatures cause damage in different physiological stages (seedling, reproductive stage and grain filling), resulting in a reduction in crop yield. Low temperatures are a major environmental factor limiting the productivity and the geographic areas where agriculture can be developed.

Changes in environmental conditions make plants reprogramme metabolic fluxes because cold temperatures produce high metabolic requirements to maintain normal physiological processes. Chilling treatments of sensitive tissues increases the activity of invertase, catalase, pyruvate decarboxylase, glucose-6-phosphate dehydrogenase and phosphoenolpyruvate carboxykinase. Likewise, decreases have been observed in a number of systems including malate dehydrogenase and amylase (Lyon, 1973).

Plants that have evolved with mechanisms of tolerance and adaptation to cold have C_3 type photosynthesis and rapidly mobilize the reserves stored. Moreover, changes in starch metabolism and raffinose family oligosaccharide synthesis are all participants in the global response to cold stress (Janska et al., 2010).

Accumulations of soluble sugars from the hydrolysis of starch (Chen et al., 2014) and their roles in stabilizing biological components, particularly for raffinose family oligosaccharides (RFO) (Tarkowski and Van den Ende, 2015), are much-studied processes in plant physiology to understand the effects of cold and cold acclimation.

It has been reported that the accumulation of galactinol assimilates such as glucose, fructose and sucrose, as well as changes in the biosynthesis of protein lipids, are adopted strategies for cold stress tolerance in plants; these act as cryoprotective molecules (Rodziewicz et al., 2014).

In C_4 plants such as maize (*Zea mays*), the leaf structure minimizes photorespiration, which is a major source of ROS in C_3 plants (Foyer, 2002.)

Changes in environmental conditions such as cold temperatures associated with light energy result in an imbalance between the light energy absorbed through photochemistry versus the energy utilized through metabolism, which reflects the relative reduction state of the photosystem, generating ROS. This acts as a signal to influence the nuclear expression of a specific cold-acclimation gene (Huner et al., 1998).

Photosynthesis and Carbon Metabolism

Several authors have shown that the rate of photosynthesis decreases in higher plants during exposure under low temperatures. This reduction is due to stomatal closure and the consequent disability for CO_2 fixation. On the other hand, cold temperatures bring about photoinhibition of photosystem II (PSII) caused by the enhanced production of reactive oxygen species damaging the photosynthetic machine.

The key enzyme for CO_2 incorporation is ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBP). It has been postulated that in seedlings subjected to cold, large RuBP subunits and RuBP-binding protein were downregulated, which may suggest chloroplast damage (Rodziewicz et al., 2014). Furthermore, it has been shown in rice (*Oryza sativa*) seedlings that synthesis of RuBP is drastically reduced after cold exposure (Hahn and Walbot, 1989). In wheat (*Triticum aestivum*) exposed to prolonged cold, stress fragmentation of RuBP was also evidenced in proteomics profile; it was suggested that RuBP proteolysis causes sugar accumulation during cold exposure (Rinalducci et al., 2011).

Regardless of the phenological state of the plant (vegetative or reproductive), cold-sensitive wheat is affected as photosystem proteins and protein related to electron transport are down-regulated, causing alterations in the flow of electrons in the chloroplast (Rinalducci et al., 2011; Xu et al., 2013). These proteins were enhanced in cold-tolerant wheat (Xu et al., 2013).

However, in rice seedlings, the proteins related to the generation of energy and sugar biosynthesis are activated under conditions of cold temperatures (Makoto Hashimoto and Komatsu, 2007).

The transcriptomics profile of rice seedling reveals that the genes involved in photosynthetic processes PSI and PSII were down-regulated (Kyonoshin Maruyama et al., 2014). RNA sequencing studies in the legume *Lotus japonicus* subjected to growth at low temperatures also show down-regulation in genes corresponding to energy metabolism that affect the photosynthetic process and chloroplast development (Calzadilla et al., 2016). In soybean (*Glycine max*), comparative proteomic analysis of seedling leaves of cold-tolerant and -sensitive cultivars indicated that cold stress also affects photosystem proteins, indicating the tolerance is caused by less energy depletion in the tolerant cultivar (Tian et al., 2015). The same result was found in maize seedling where a proteomics profile based in i-TRAQ revealed which proteins are involved in photosynthesis; light harvesting and light reaction are down-regulated (Wang et al., 2016).

On the other hand, the opposite results were obtained in cold-tolerant soybean seed germinates exposed to 4°C, where the proteomic profile revealed an increase in most proteins linked to energy metabolism (Cheng et al., 2010).

The Role of Carbohydrates in Response to Cold Stress

Plants produce biochemical changes in response to low temperatures as a mechanism of adaptation and defense. A transition occurs when the metabolism of starch is directed towards a metabolism aimed at accumulating oligosaccharides as cryoprotectants giving an osmotic adjustment response (Janska et al., 2010; Beck et al., 2007; Xiong and Zhu, 2002; Guy et al., 1992).

It could be said that this increase in the amount of sucrose, like a storage carbohydrate, is because it can be easily remobilized depending on the metabolic needs under stress conditions (Guy et al., 1992).

In wheat plants, seedling and reproductive stage exposed to chilling showed an increase in soluble carbohydrates (Savitch et al., 2000; Vargas et al., 2007; Rinalducci et al., 2011; Xu et al., 2013), especially sucrose, and an increase in the capacity for sucrose utilization through the biosynthesis of fructans, accompanied by an induction of the activity of the enzyme invertase, exhibiting a regulation mediated by free sugars in response to the cold (Savitch et al., 2000; Vargas et al., 2007). The same regulation was observed in legume nodules of *Lotus japonicus* in non-stressing conditions, indicating a possible role of invertases in producing hexoses for starch production when the metabolic requirements are high (Flemetakis et al., 2006).

RNA sequencing in seeds of tolerant indica rice detected high expression in enzymes involved in the synthesis of sucrose and breakdown of polysaccharides to generate simple sugars, such as glucose, compared to cold-sensitive indica rice (Dametto et al., 2015).

Comparisons between two soybean cultivars (tolerant and sensitive) in seedling stage reveal that cold stress affects the total amount of soluble carbohydrates, decreasing in both cultivars. At the same time, the protein profiles show a reduction in pentoses phosphate and glycolysis pathways for both cultivars (Tian et al., 2015). Other reports in seed soybean showed that proteins associated with carbohydrate enhanced starch metabolism as well as increasing the granule-bound starch gene (Cheng et al., 2010). In *Lotus japonicus* those genes of starch and sucrose metabolism also showed up-regulation (Calzadilla et al., 2016). In maize, most of the proteins associated with carbohydrate metabolism were accumulated after the chilling stress (Wang et al., 2016).

Metabolome analyses in rice seedling treated under low temperature revealed that levels of monosaccharides increased, while transcriptomics analyses indicated that several genes encoding enzymes involved in starch degradation, sucrose metabolism and the glyoxylate cycle are upregulated and that these changes are correlated with the accumulation of glucose, fructose and sucrose. In particular, high expression levels of genes encoding isocitrate lyase and malate synthase in the glyoxylate cycle correlate with increased glucose levels (Maruyama et al., 2014). In the reproductive stage of rice (booting stage) the starch and sucrose contents in the leaf blades and stems after panicle initiation did not undergo significant changes and carbon availability from source tissues is unlikely to affect chilling sensitivity in spikelet at the booting stage (Suzuki et al., 2015). Different results were reported in three maize inbred lines where a decrease in sucrose and glucose levels was found when analyzed by metabolism profile (Sun et al., 2016).

In another important forage legume, when two cultivars (*Medicago sativa* and *Medicago falcata*) were compared, both showed sugar accumulation (sucrose, galactinol and raffinose), although *M. sativa* displaying show accumulation of sugars. In *M. falcata* all sugars accumulated rapidly and stayed at high levels except for raffinose (Zhuo et al., 2013).

The raffinose family oligosaccharides (RFOs) are synthesized from sucrose by the subsequent addition of activated galactinol moieties donated by galactinol (ElSayed et al., 2014). Raffinose was accumulated in leaves accompanied by an increase in galactinol (Saito et al., 2011). It has also been observed that levels of transcripts of raffinose synthase decreased under cold stress but are increased under dehydration conditions (Maruyama et al., 2014).

Microarray analysis of rice plant at booting stage revealed that cold treatments during vegetative growth provoked up-regulation of a raffinose synthase gene, showing the same pattern as the heat shock protein genes (Suzuki et al., 2015). It has been proposed that higher levels of raffinose synthase, as well as raffinose, can assist in osmotic adjustments as well as in membrane and protein stabilization and to protect plants from oxidative stress caused by cold stress (Suzuki et al., 2015; ElSayed et al., 2014). Furthermore, there is evidence that in some plant species, change in RFOs is part of a mechanism for carbon storage rather than protection against environmental changes (ElSayed et al., 2014). Transcriptional up-regulation of the raffinose oligosaccharide pathway results in accumulation of monosaccharides and disaccharides, including glucose, fructose, sucrose, galactinol and raffinose (Jansko et al., 2010).

Higher levels of the transcript of the galactinol synthase encoded gene (MfGolS1) were induced and maintained in *M. falcata* than in *M. sativa* during cold acclimation, in accordance with the accumulation of sugars and the differential cold tolerance between *M. falcata* and *M. sativa* (Zhuo et al., 2013).

Galactinol synthase is the enzyme that catalyzes the first step of RFOs. Transgenic tobacco that overexpresses the exogenous gene MfGolS1 of *M. falcata* turned out to be more tolerant to freezing and chilling (Zhuo et al., 2013).

Trehalose is another nonreducing disaccharide that serves as a protector against stress. Trehalose synthesized via a phosphorylated intermediate, trehalose 6-phosphate (Tre6P), has been a reporter that the gene of trehalose-6-phosphate (TPS) increases in freezing stress (Song et al., 2016a). There is a strong correlation between sucrose and Tre6P. Parallel changes in their levels indicate that synthesis and degradation of Tre6P may be regulated by sucrose (Lunn et al., 2014). The demand for starch is regulated by sucrose-dependent changes in Tre6P that modulate the rate of starch breakdown according to the demand for sucrose (Lunn et al., 2014).

An accumulation of trehalose may act as a regulator of stress, giving greater tolerance under low temperatures. Transgenic rice plants which contained the exogenous gene trehalose biosynthetic (otsA and otsB) from *Escherichia coli* exhibited constant plant growth, less photo-oxidative damage and more favorable mineral balance under low-temperature stress conditions (Garg et al., 2002).

Fatty Acid Metabolism

Fatty acids are components of cellular membrane, thylakoid membrane and cutin waxes; trienoic fatty acids (TAs), hexadecatrienoic acid (16:3) and linolenic acid (18:3) are the major polyunsaturated fatty acid species in membrane lipids (Upchurch, 2008), and changes in their regulated plant response against low temperatures. Cold temperatures cause damage to the lipid membrane; these oxidative lipid injuries are generated by ROS resulting in lipid peroxidation and changes in lipid compositions.

In physiological conditions, the membrane lipid is in the liquid crystal phase, but under low-temperature stress, it is transformed from the liquid phase into the gel phase, thus increasing the permeability of the membrane (Lyons, 1973; Chen et al., 2014; Tarkowski and Van den Ende, 2015). This arrangement of membrane fluidity, with the transition to gel phase, is accompanied by an increase in the proportion of unsaturated fatty acids (Beck et al., 2007; Janska et al., 2010; Chen et al., 2014).

Releasing α-linolenic acid (18:3) is a way of modulating the membrane flow, in chloroplast saturated phosphatidylglycerol (PG), with saturated fatty acids (16:0, 18:0) playing a key role in acclimatization of plants under chilling. Increased TAs in the plasma membrane enhance low-temperature tolerance in plants during the early growth stage (Iba, 2002; Upchurch, 2008).

The chloroplast is a sensitive target of low temperatures; differences between lipid compositions in chloroplasts may be the cause of plant sensitivity or tolerance to cold stress. The content of PGs in chloroplasts is 16:0 or 16:1; in tolerant plants the levels of 16:0, 16:1 and 18:1 are less than in sensitive plants (Iba, 2002).

Alfalfa studies comparing tolerant and cold-sensitive varieties showed that low-temperature-resistant varieties contained a higher percentage of polyunsaturated fatty acids in chloroplast membranes (Peoples et al., 1978).

Willemot (1977) described that saturated fatty acids at low temperature in wheat are not related to frost hardiness. Furthermore, in alfalfa it has been shown that linoleic acid accumulates at low temperature while wheat accumulates linolenic acid. In rice there is a positive relationship between the unsaturated fatty acid composition of the chloroplast membrane and the photosynthetic tolerance to chilling (Zhu et al., 2007).

A metabolome study in maize showed that triacylglycerides and diacylglycerides produced from the glycerolipid metabolic pathway significantly decreased when plant seedlings were exposed to low temperatures (Sun et al., 2016). In soybean, protein profiles comparing a sensitive and tolerant variety show that the low-temperature-tolerant cultivar improves the biosynthesis of fatty acids (Tian et al., 2015).

RNA sequencing in rice and lotus reveals that in sensitive plants there is a down-regulated gene in the metabolic lipid pathway (Dametto et al., 2015; Calzadilla et al., 2016). This indicates this is a generalized response in plants against cold stress where a regulation metabolic process exists related to unsaturated fatty acid accumulation.

Summary

There is a general response for plants against cold stress. The metabolic changes focus on counteracting the oxidative stress in the chloroplast and lowering the photoinhibition, particularly regulating the photosynthesis and carbohydrate metabolism.

The biochemical response produced by cold damage is generally associated with the accumulation of unsaturated fatty acids in order to decrease lipid peroxidation. Sugar accumulation, seems to be a response to support growth under temperature stress, acting like photoprotective molecules, lowering levels of ROS, and like osmotic molecules, regulating the osmotic imbalance caused by the cold. This mechanism is summarized in Figure 1.1.

As a strategy for future breeding projects it is thought that a plant phenotype that is more energy efficient at the level of chloroplast would lower the levels of ROS produced by the cold and the consequent photoinhibition. This would make the plant more metabolically efficient where the biochemical processes are geared towards growth rather than repair of damage, resulting in a greater grain yield in crop species.

Water Deficit

Plants Water Balance

Plant water balance explains the behavior of plants in terms of how they control the hydration of their cells, which has important implications in the physiological and metabolic processes that determine the quantity and quality of plant growth (Passioura et al., 2010). The plant water balance is determined by the ratio between the fraction of water lost in evaporation (transpiration) to the atmosphere and its absorption from the soil. When transpiration exceeds absorption, the relative water content (RWC) and the cellular volume decrease, determining the loss of cell turgor and at the same time increasing the solute levels in the cell, so osmotic potential (π) and water potential (ψ) fall (Lawlor and Cornic, 2002). This situation could be modified by osmotic adjustment (OA) in species that have such a defense mechanism. OA has been and is well established as a major regulator of turgor and stomata conductance (Gs) in drought (Blum, 2016). Turner and Jones (1980) indicate that OA was effective in sustaining turgor, RWC and Gs at low leaf water potential in sorghum. A lower state of cell turgor and RWC causes slow growth and Gs. In this context two parameters describe the water status of plants: RWC and ψ (Nobel, 2009). RWC is a measure of relative change in cell volume; ψ is the result of cell turgor and π, and thus depends both on solute concentration and cell wall rigidity and does not relate directly to cell volume (Kaiser, 1987; Jones, 2007). OA together with cell wall rigidity regulate turgor under dehydration, where the former is generally more effective and prevalent than the latter (Bartlett et al., 2012). Small cells are generally more conducive to OA than large ones. It is recognized that turgor, Gs and growth can be regulated by hydraulic and/or hormonal signals, directly or indirectly (Blum, 2016).

Plant Strategies to Mitigate Damage from Dehydration

From an agricultural perspective, drought is ultimately defined in terms of its effects on yield, since this is the relevant issue when addressing the improvement of crop production under water-limited environments (Passioura, 2007). Most plants that are grown in field conditions experience water stress during part of their growing cycle, especially at midday and early afternoon in the summer or due to the scarcity or absence of rain for long periods of time. This threat affects phenology, carbon fixation, distribution of assimilates and plant reproduction (Fuad-Hassan et al., 2008); for example, legumes are highly sensitive to water deficit especially during the reproductive period, flowering and pod filling (Araújo et al., 2015). Consequently, the timing of water deficits during the season (e.g. sowing, crop establishment,

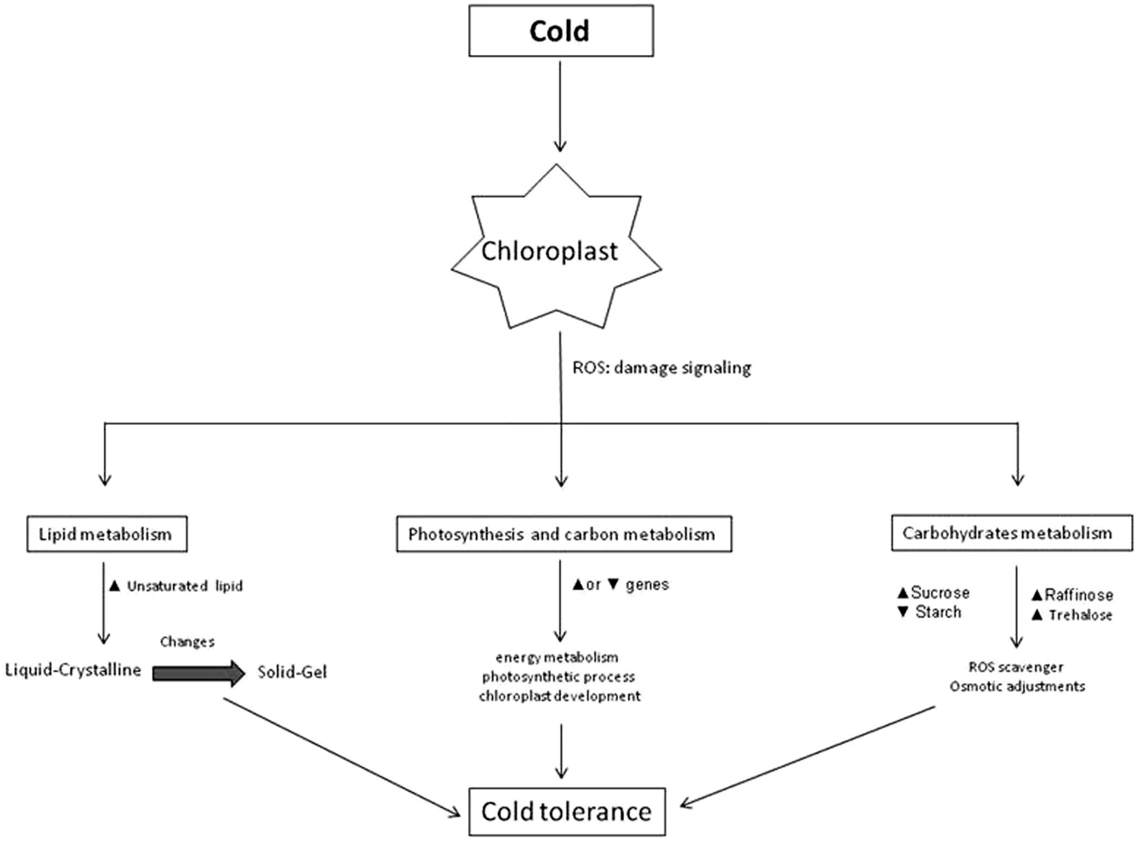

FIGURE 1.1 Schematic representation of how metabolic routes vary in response to cold.

flowering or grain filling) may have a much larger impact on yield than the intensity of drought per se (Pinheiro and Chaves, 2010). In this way, to maintain productivity, agriculture uses about 70% of water resources in the world. It is estimated that, by 2030, the requirement for irrigation will increase by 14% (FAO, 2009).

Mesophyte species that experience water stress modify or adjust their cell metabolism to the new conditions imposed by stress. When the regulation is inadequate and the metabolism is not adjusted to maintain its functions, they trigger a series of harmful effects that can cause the death of the vegetable. Regulation is strongly influenced by species and environment. Metabolic changes involve biochemical, physiological and structural modifications (Passioura, 2007). With some exceptions, the lack of water of tissues below a critical level is accompanied by irreversible changes in the structure and finally, the death of the plant (Azcón-Bieto and Talón, 2008). In nature, plants can either be subjected to slowly developing water shortage (days, weeks or months) or face short-term water deficits (hours to days). In the case of slow water deficits, plants can either escape dehydration by shortening their life cycle or optimize their resource gain in the long term through acclimation responses. In some modern maize hybrids the anthesis-silking interval under drought has become shorter and selection has possibly led to an increase in the growth of spikelets (Bänziger and Cooper, 2001). In the case of rapid dehydration, plants react to minimizing water loss or exhibiting metabolic protection (induced or constitutive) against the damaging effects of dehydration and co-developing oxidative stress (Chaves et al., 2003). Fast and slow desiccation can have totally different results in terms of physiological response or adaptation (McDonald and Davies, 1996), but the importance of time in shaping plant response may change dramatically according to genotype and environment (Chaves et al., 2003).

Plants can strengthen their response to a drought by avoiding tissue dehydration, maintaining the potential water as high as possible or by tolerating low tissue water potential using metabolic strategies. Although many genes are induced by water deficit, the molecular functions of all these are not known. In addition, the impact of a change in gene expression of a gene with a known function, such as an enzymatic function, on cellular homeostasis may not be exactly understood (Bray, 2007). Dehydration avoidance is associated with a variety of adaptive traits involving minimizing water loss and maximizing water uptake. Water loss is minimized by density or regulation stomatal (Bell et al., 2007), by reducing light absorbance or by decreasing leaf area due to less cell division and expansion rates in leaves. One of the earliest water-saving mechanisms, present in a great majority of plants, is reduced leaf growth (Aguirrezábal et al., 2006) or the earlier senescence of older leaves in the case of prolonged stress (Pinheiro and Chaves, 2010). This reduction in foliage dimension or lower stomata density leads to a decreased transpiration area (Quan et al., 2016). Water uptake is maximized by adjusting the growth pattern to increase growth of roots. This is the main resource to maximize water absorption. This response is mediated by hormones: abscisic acid (ABA), ethylene and their interactions (Wilkinson and Davies, 2002). Changes in the root/shoot ratio as well as temporary accumulation of reserves in the stem occur in several species under water deficit (Chaves et al., 2003). As the key process of primary metabolism, photosynthesis plays a central role in plant performance under drought (Pinheiro and Chaves, 2010). The decline observed in leaf net carbon assimilation (A) as a result of plant water deficits is followed by an alteration and partitioning of the photo-assimilates at the whole plant level, corresponding in general to an increase in the root/shoot ratio (Sharp, 2002).

Experience from drought-resistant cereal cultivation during a century of scientific breeding clearly indicates that drought resistance in crop plants under stress is mainly derived from their ability to sustain tissue hydration during drought (i.e. dehydration avoidance), rather than an ability to sustain biological function when tissues are dehydrated (i.e. dehydration tolerance) (Araus et al., 2012).

Response Mechanisms That Take Place in Leaves

In order to avoid excessive water loss in times of drought, regulation of stomata aperture together with the reduction of the leaf area are the immediate responses of plants, which could result in a dehydration cell that would produce xylem cavitation, causing plant death (Comstok, 2002). However, a stomatal aperture is essential in leaf cooling by latent heat exchange, and this characteristic is an objective of selection in plant breeding (Lu et al., 1997). For example, many species have been classified as isohydric or anisohydric depending on the sensitivity of stomata to soil dehydration. Isohydric plants are those that close their stomata when they sense a drop in soil water potential or an increase in atmospheric demand. On the other hand, anisohydric plants continue to transpire even when soil water content diminishes, because these plants are keeping their stomata open longer (Tardieu and Simonneau, 1998). The different response of stomata to water scarcity is also associated with different root/shoot ratios, with the anisohydric stomatal behavior often being associated with larger root systems and high capacity for osmoregulation that supports water uptake until soil water content is low. Osmoregulation requires a dehydration signal to be developed, more likely to take place in aniso- than in isohydric plants. The anisohydric strategy allows a closer match between water availability and consumption, with a positive impact on season growth (Chaves et al., 2016). Regardless of the mechanism of perception and signaling that causes stomatal closure, many plants show a tendency to increase water use efficiency (WUE) when the stress is moderate as a result of a non-linear relationship between carbon assimilation and Gs, by which the plant restricts the loss of water without excessively affecting photosynthesis (Blum, 2005; Taiz and Zeiger, 2003). When comparing C_3 and C_4 species it is apparent that C_4 plants exhibit higher WUE (A/E ratio) due to higher A and lower transpiration (E). In warm regions, where C_4 species evolved, photorespiration is stimulated considerably, as well as the demand for transpiration for cooling. By increasing CO_2 around the carboxylating enzyme Rubisco (RuBP), C_4 plants greatly enhanced carboxylation efficiency and were able to inhibit photorespiration (Sage, 2004). By producing smaller stomata density or reducing stomata aperture plants will function at low stomata conductance (Gs) and have lower E (Chaves et al., 2016). However, in this case, the CO_2 concentration at the RuBP site in the mesophyll cells is limited (Perdomo et al., 2017). In this sense, Perdomo et al. (2017) observed that the limitations to photosynthesis under drought were mainly caused by a stomata closure (lower Gs) and increased leaf resistance to CO_2 transport from the atmosphere to the site of carboxylation (diffusive limitations) in C_3 and C_4 species. Conversely, under the combination of water deficit and heat stress, biochemical limitations have been observed with decreased RuBP activation and impaired ATP synthesis, which is due to a decrease in electron transport. Experimental studies on CO_2 assimilation of mesophytic C_3 plants under water stress revealed a decreased relative water content (RWC), actual rate of A and potential rate (A_{pot}). In this way, there are two general types of relation of A_{pot} to RWC, which are called Type 1 and Type 2. Type 1 has two main phases. As RWC decreases from 100% to 75%, A_{pot} is unaffected, but decreasing Gs results in smaller A, and lower CO_2 concentration inside the leaf (C_i) and in the chloroplast (C_c), the latter falling possibly to the compensation point. Below 75% RWC, there is metabolic inhibition of A_{pot}, inhibition of A then being partly reversible by elevated CO_2; Gs regulates A progressively less, and C_i and CO_2 compensation points rise. In the Type 2 response, A_{pot} decreases progressively at RWC 100% to 75%, with A being progressively less restored to the unstressed value by elevated CO_2. Decreased Gs leads to a lower C_i and C_c but they probably do not reach compensation point: Gs becomes progressively less important and metabolic limitations more important as RWC falls (Lawlor and Cornic, 2002). The primary effect of low RWC on A_{pot} is most probably caused by limited RuBP synthesis, RuBP activity or activation state, as a result of decreased ATP synthesis, either through inhibition of coupling factor activity or amount due to increased ion concentration or impaired activation of RuBP by Rubisco activase (Perdomo et al., 2017). Electron transport is maintained (but down-regulated) over a wide range of RWC (Sage et al., 2008; Taylor et al., 2011). Metabolic imbalance results in amino acid accumulation and decreased protein synthesis. These conditions profoundly affect cell functions and ultimately cause an excess of radiant energy that is not used for photosynthesis and that the plant must eliminate in order to avoid the overproduction of reactive chemical species that potentially can produce oxidative damages that would compromise the photosynthetic (Chaves et al., 2003). Autotrophic organisms have direct and indirect mechanisms that capture the excess of incident photons (photoreceptors, photochromes, neocromes, phytochromes, rhodopses and cryptochromes), variation of pH in the thylakoid lumen, changes in the oxidation-reduction state, production of reactive oxygen species (ROS) and accumulation of metabolites, which will induce changes in nuclear gene expression and gene expression in the plastid. These mechanisms attempt to decrease the damage caused by the adverse situation (Li et al., 2009). In order to avoid excess light, plants can reduce light absorbance by leaf rolling, a dense trichome layer increasing reflectance and steep leaf angles. They can divert absorbed light by photochemical reactions to other processes such as thermal dissipation (Pastenes et al., 2004; Baker, 2008). In fact, it is widely accepted that photosynthesis regulation in response to the environment is highly dynamic and is modulated in the short term by thermal energy dissipation. This increase in energy dissipation is linked (at least partially) to a parallel increase in photoprotective carotenoid levels. In this way, the "xanthophyll cycle" plays a primordial role in the thermal dissipation process, which consists of light-dependent interconversion of three xanthophylls (oxygenated carotenoids): violaxanthin, anteraxanthin and zeaxanthin. This is a cyclic reaction involving a de-epoxidation sequence of violaxanthin di-epoxide via anteroxanthine mono-epoxide to form zeaxanthin (without epoxy groups). The cycle is regulated by light; violaxanthin is de-epoxidated to anteraxanthin and zeaxanthin under conditions of high photon flux (or when photosynthetic activity is diminished by stress), while in the dark (or when the stress factor is absent), zeaxanthin is again epoxidized to violaxanthin (Demming-Adams and Adams, 1996; Nelson and Yocum, 2006). Moreover, other processes have significant photoprotective and stabilizing functions, including the antioxidant properties of vitamin E (α-tocopherol), a constitutive component of the lipid matrix of thylakoid membranes (Li et al., 2009). In species under water deficit, the use of absorbed light (photosynthesis or photorespiration) and thermal dissipation is not sufficient to retain excess energy; electrons in a highly excited state are transferred to molecular oxygen (O_2) that form the reactive oxygen species (ROS), such as H_2O_2, O_2^-, HO^- and $^1O_2$. All these molecules are highly toxic and can cause oxidative damage to proteins, DNA and lipids (Miller et al., 2010). In this situation, the plant has antioxidant molecules and enzymes that are in different cell compartments and can scavenge ROS (superoxide dismutase, catalases, ascorbate-glutathione cycle such as glutathione reductase and ascorbate peroxidases). The antioxidant activity depends on the degree of severity of stress, genotype and stage of development. The acclimatization of plants to drought is associated with increased activity of antioxidant enzymes that maintain the concentration of ROS at relatively low levels (Signorelli et al., 2013; Quan et al., 2016). On the other hand, seedlings subjected to water deficit show nitric oxide (NO) production (Arasimowicz-Jelonek et al., 2009). However, when there is a deregulated synthesis or overproduction of NO that may have toxic physiological consequences, it results in nitrosative stress due to reactive nitrogen species (RNS) formation. RNS are formed by the interaction of NO with free radicals and oxygen. RNS include NO^-, nitrogen dioxide (NO_2^-), S-nitrosothiols (SNOs) and peroxynitrite ($ONOO^-$) (Airaki et al., 2011). Water stress in *Lotus japonicus* results in an increase in NO levels and reduced S-nitrosoglutathione reductase activity (an enzyme that maintains low levels of RNS), especially in roots (Signorelli et al., 2013). Under environmental stress, an increase in ROS and RNS levels can cause damage in cells, but it must be pointed out that both ROS and RNS can also serve as secondary messengers in signaling for the activation of defense responses to pathogens, abiotic stress, programmed cell death and development (Suzuki and Mittler, 2006; Arasimowicz-Jelonek et al., 2009; Gill and Tuteja, 2010; Miller et al., 2010, Airaki et al., 2011; Signorelli et al., 2013).

Response Mechanisms That Take Place in Roots

Root systems are responsible for water and nutrient uptake and provide physical stability, and store nutrients and carbohydrates. In addition, roots may act as sensors for water deficit conditions and send signals to shoots above ground. It is well documented that species adapted to dry climatic regimes generally have higher root/shoot ratios and deeper root systems than species that are suited to humid climatic conditions (Brunner et al., 2015). Although the root/shoot ratio tends to increase, the biomass of fine roots in particular is often reduced as a consequence of reduced transpiration and respiration rates. The benefit, however, is that young roots are able to take up water more efficiently than older ones, and thus, root shedding and re-growth represent a more suitable acclimation of plants to reduced water supply if the plant can afford this strategy. In experiments with trees it was observed that whether a tree maintains old roots or sheds old roots and produces new ones in response to drought is determined by the benefit to cost ratio in terms of water uptake and carbon expenditure. Root shedding and the construction of new roots mean the investment of a considerable amount of energy in the process of root turnover (Eissenstat et al., 2000). Before this, plants cease growth and close the stomata to prevent water loss under drought conditions, which results in a simultaneous decrease in photosynthesis. However, maintenance respiration responds more slowly to drought than photosynthesis, resulting in a carbon deficit and forcing the plant to utilize stored carbohydrates. If the carbon deficit persists for a long time, carbohydrates will be depleted and plants will experience carbon starvation, resulting in plant mortality. In the roots of *Robinia*, Yan et al. (2017) observed an increase in soluble sugar but a decrease in starch, indicating that the roots began to utilize the starch, creating a carbon deficit in the roots. Regier et al. (2009) applied drought conditions to two contrasting *Populus nigra* clones and observed that the drought-adapted clone had significantly more starch but significantly less sucrose, glucose and fructose in the roots and conversely a drought-sensitive clone had a reduction of carbohydrate due to lower starch levels inducing degradation of starch to maintain root respiration. In soybean, under severe water deficit, there was an increase in transcripts associated with starch synthesis and a decrease in transcripts associated with starch degradation. Conversely, galactinol and raffinose synthase related genes were up-regulated, which might enhance osmotic tolerance in the root (Song et al., 2016b). In this way, the elevated level of proline found in alfalfa roots indicates the ability to regulate water deficit stress tolerance (Rahman et al., 2016). Generally, a decrease in soluble sugars is observed in the branch, stem, bark and root tissues after rewatering due to recovery of tissue growth (Brunner et al., 2015; Yan et al., 2017).

Summary

Cold, drought and salinity are those environmental factors which affect plants in many respects and which, due to their widespread occurrence, cause the most fatal economic losses in agriculture. All three forms of abiotic stress affect the water relations of a plant on the cellular as well as whole plant level, causing specific as well as unspecific damage (Figure 1.2) and responses. The plant's response to these stresses (drought, salt and cold) is through the response mechanisms that are raised at both molecular and cellular levels, as well as physiological and biochemical, which allow them to acclimate and survive stress. In general, the first step in switching on a molecular response in response to an environmental signal is its perception by specific receptors; these are physical signals (changes in the pressure of cell turgor, alterations in the walls and cellular volume) that are then converted to biochemical

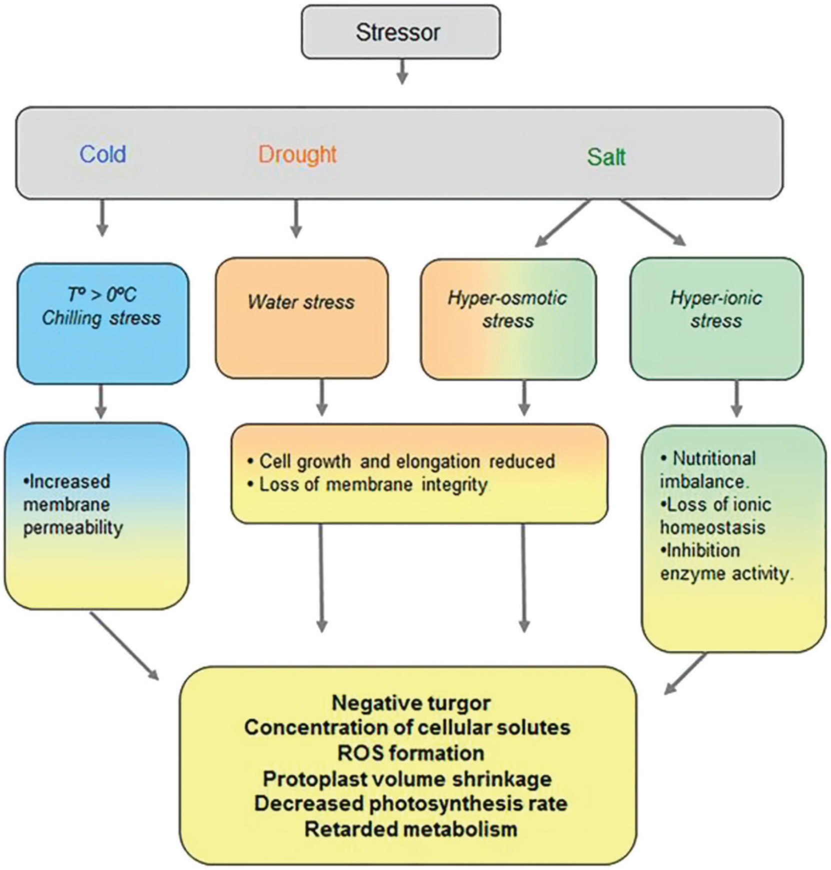

FIGURE 1.2 Similar (bold types) and dissimilar damages produced by cold, salt and drought in plant tissues.

signals, which are generated in response to stress (Bray, 2007). These include receptor-like kinases, receptor tyrosine kinases, G-protein coupled receptors, iontropic channel related receptors, histidine kinases, nuclear hormone receptors and extra- and intracellular Ca^{2+} sensors. Ca^{2+} influx and histidine kinases have been identified in response to cold. It has been suggested that in *Arabidopsis* a heterotrimeric G-protein is involved in ABA response in guard cells (Xiong and Ishitani, 2006). Then, followed by the generation of secondary messengers (inositol phosphates, ROS) that can modulate the intracellular Ca^{2+} level and initiate a signal transduction cascade that involves protein phosphorylation/dephosphorylation, where different Ca^{2+} sensors are included, a protein decodes their signals and has a Ca^{2+} binding motif, the so-called EF hand motif: calmodulins (CaMs), calcineurin B-like proteins (CBLs), Ca^{2+}-dependent protein kinases (CDPKs), mitogen-activated protein kinase (MAPKs) and phospholipid-cleaving enzymes (Shi, 2007). In salt stress, it is important to emphasize the ion-specific signaling pathway SOS (salt overlay sensitive), which responds to changes of Ca^{2+} levels in cytoplasm, described in *A. thaliana* (Zhou et al., 2007). Finally, these would reach a large number of genes, enzymes, hormones, and metabolites. The products of these genes can participate in the generation of regulatory molecules such as ABA, and ethylene and salicylic acid, which in turn can initiate a secondary signaling process (Xiong et al., 2002). The different environmental variables that determine osmotic stress constitute a complex of stimuli that possess different and sometimes related attributes in which each one of them provides particular information to the cells. Given this multiplicity of signals, it is expected that the plant possesses multiple primary sensors that perceive the signal of stress. The increase of Ca^{2+} in cytoplasm, as a result of the influx from apoplast or the release of intracellular compartments, is an early response to osmotic stress (Shi, 2007). The products of inducible genes to osmotic stress can be classified into two groups: the first group includes functional proteins (which participate directly in the biochemical mechanisms of damage control, repair and acclimatization: aquaporins and some key enzymes of osmolytes biosynthesis, chaperones, antioxidants), whereas the second group comprises regulatory proteins involved in signal transduction and gene expression (e.g. transcription factors, protein kinases, protein phosphatases) as well as diverse effectors involved in signaling (e.g. calmodulin-binding protein, SOS pathways; Seki et al., 2003). Hundreds of genes are induced or repressed under osmotic stress. Many of these stress-inducible genes are activated by ABA, and their products may improve tolerance to stress (Xiong, 2007). It is not surprising that gene expression is regulated by this phytohormone, although not all genes that are induced by stress are regulated by ABA, indicating the existence of several signaling pathways (Ishitani et al., 1997). Among the most important pathways are ABA-dependent and ABA-independent, which isolate and characterize the *cis*-regulatory elements and the transcriptional factors responsible for its activation (Busk and Pages, 1998). The ABA-regulated promoters, called ABRE (ABA response elements), contain ACGT

TABLE 1.1

Promotors, *Cis*-Regulatory Elements and Transcription Factors in Response to Osmotic Stress

Promotors	*Cis* Elements	Transcription Factors	Stressor
RD29A	ABRE	CBF/DREB1	Cold
RD29A	DRE/CRT	DREB2	Salt, ABA and drought
RD29B	ABRE	bZIP	Salt and drought
RD22	MYB/MYC	MYBR/MYCR	Drought and ABA

nucleotides as the *core* of their sequence and form part of the elements called G-box. More than 20 ABREs have been described in genes that respond to dehydration and drought, which bind to trans- factors regulated by ABA, such as bZIP (Kobayashi et al., 2008). Also, other ABA-responsive transcription factors known as MYBR/MYCR constitute an indirect pathway for ABA regulation through the R22 promoter gene. On the other hand, ABA-independent genes are characterized by containing a conserved dehydration response element (DRE, TACCGACAT) in their promoter region, related to gene regulation by interaction with an ABA-independent signaling cascade and matched by the gene RD29B promoter. It is a faster response route than the previous one (Table 1.1). This was discovered through studies of the RD29A promoter gene, which is induced by both ABA-dependent and independent pathways (Xiong et al., 2002; Shinozaki and Yamaguchi-Shinozaki, 2007). The genes that are upregulated by ABA (a) encode enzymes that function in the biosynthesis of compatible solutes that could lower leaf water potential and facilitate water uptake and retention, (b) can directly detoxify ROS (Jiang and Zhang, 2002) and (c) encode polypeptides that may help to restore the native structure of abnormally folded proteins or could promote the degradation of unfolded proteins that cannot be repaired (Xiong et al., 2007). Although osmotic stress alone can activate these stress-responsive genes, ABA can synergistically enhance their expression, enhancing the ability of the plants to respond to stress (Tuteja et al., 2011). In addition, a complex network of response involving ABA and PAs and/or nitric oxide (Arasimowicz-Jelonek et al., 2009) has been identified and observed in different species, such as *Lotus tenuis* (Espasandin et al., 2018), *Coffea canephora* (Marracini et al., 2012) and *Lycopersicum esculentum* (Diao et al., 2017) exposed to salt, water and cold stress, respectively. Finally, the vegetal metabolism is altered, inducing biochemical and physiological responses that create tolerance (Figure 1.3).

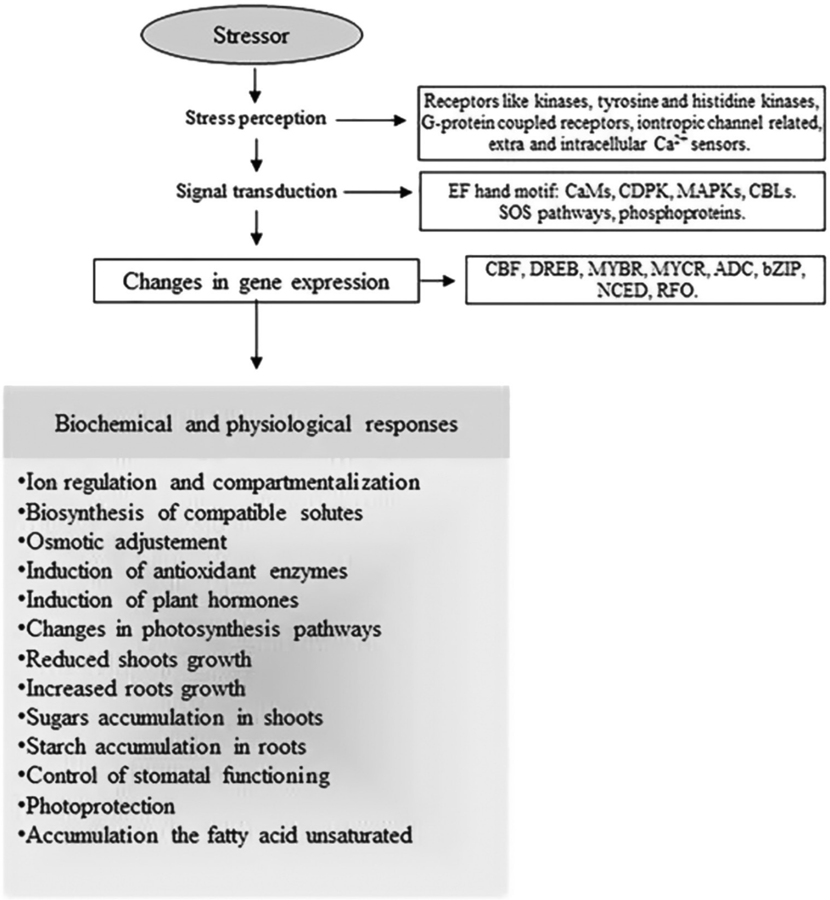

FIGURE 1.3 Biochemical and physiological responses to drought, salt and cold stress in plants.

REFERENCES

Abogadallah, G. M. 2010. Antioxidative defense under salt stress. *Plant Signaling and Behavior* 5(4):369–374.

Aguirrezábal, L., Bouchier-Combaud, S., Radziejwoski, A., Dauzat, M., Cookson, S.J., Granier, G. 2006. Plasticity to soil water deficit in *Arabidopsis thaliana*: Dissection of leaf development into underlying growth dynamic and cellular variables reveals invisible phenotypes. *Plant, Cell and Environment* 29:2216–2227.

Ahmads, S., Khan, N., Iqbal, M.Z. 2002. Salt tolerance of cotton (*Gossypium hirsutum L.*). *Asian Journal of Plant Science* 1:715–719.

Airaki, M., Sánchez-Moreno, L., Leterrier, M., Barroso, J.B., Palma, J.M., Corpas, F.J. 2011. Detection and quantification of S-nitrosoglutathione (GSNO) in pepper (*Capsicum annuum* L.) plant organs by LC-ES/MS. *Plant and Cell Physiology* 52:2006–2015.

Annunziata, M.G., Ciarmiello, L.F., Woodrow, P., Maximova, E., Fuggi, A., Carillo, P. 2017. Durum wheat roots adapt to salinity remodeling the cellular content of nitrogen metabolites and sucrose. *Frontiers in Plant Science* 7, Article 2035.

Arasimowicz-Jelonek, M., Floryszak-Wieczorek, J., Kubis, J. 2009. Interaction between polyamine and nitric oxide signaling in adaptive responses to drought in cucumber. *Journal of Plant Growth Regulation* 28:177–186.

Araújo, S.S., Beebe, S., Crespi, M., Delbreil, B., González, E.M., Gruber, V., Lejeune-Henaut, I., et al. 2015. Abiotic stress responses in legumes: Strategies used to cope with environmental challenges. *Critical Reviews in Plant Science* 34:237–280.

Araus, J.L., Serret, M.D., Edmeades, G.O. 2012. Phenotyping maize for adaptation to drought. *Frontiers in Physiology* 3:305.

Ashraf, M. 2009. Biotechnological approach of improving plant salt tolerance using antioxidants as markers. *Biotechnology Advance* 27:84–93.

Azcón-Bieto, J., Talón, M. 2008. *Fundamentos de Fisiología Vegetal*. 2nd edition. Interamericana-McGraw-Hill, Madrid.

Baghel, L., Kataria, S., Guruprasad, K.N. 2016. Static magnetic field treatment of seeds improves carbon and nitrogen metabolism under salinity stress in soybean. *Bioelectromagnetics* 37:455–470.

Baker, N. 2008. Chlorophyll fluorescence: A probe of photosynthesis *in vivo*. *Annual Review of Plant Biology* 59:89–113.

Bänziger, M., Cooper, M.E. 2001. Breeding for low input conditions and consequences for participatory plant breeding-examples from tropical maize and wheat. *Euphytica* 122:503–519.

Bartlett, M.K., Scoffoni, C., Sack, L. 2012. The determinants of leaf turgor loss point and prediction of drought tolerance of species and biomes: A global meta-analysis. *Ecology Letters* 15:393–405.

Beck, E.H., Fettig, S., Knake, C., Harting, K., Bhattarai, T. 2007. Specific and unspecific responses of plants to cold and drought stress. *Journal of Biosciences* 32:501–510.

Bell, L.W., Williams, A.H., Ryan, M.H., Ewing, M.A. 2007. Water relations and adaptations to increasing water deficit in three perennial legumes, *Medicago sativa*, *Dorycnium hirsutum* and *Dorycnium rectum*. *Plant and Soil* 290:231–243.

Blum, A. 2005. Drought resistance, water-use efficiency, and yield potential: Are they compatible, dissonant, or mutually exclusive? *Australian Journal of Agriculture Research* 56:1159–1168.

Blum, A. 2016. Osmotic adjustment is a prime drought stress adaptive engine in support of plant production. *Plant, Cell and Environment* 40:4–10.

Bohnert, H.J., Jensen, R.G. 1996. Strategies for engineering water-stress tolerance in plants. *Trends Biotechnology* 14:89–97.

Boyer, J.S. 2010. Drought decision making. *Journal of Experimental Botany* 61:3493–3497.

Bray, E.A. 2007. Molecular and physiological responses to water-deficit stress. In *Advances in Molecular Breeding toward Drought and Salt Tolerant Crops*. M.A. Jenks et al. (eds.). Springer, Dordrecht, the Netherlands, pp. 121–140.

Brunner, I., Herzog, C., Dawes, M.A., Arend, M., Sperisen, C. 2015. How tree roots respond to drought. *Frontiers in Plant Science* 6:547.

Busk, K., Pages, M. 1998. Regulation of abscisic acid-induced transcription. *Plant Molecular Biology* 37:425–435.

Calzadilla, P., Maiale, S., Ruiz, O., Escaray, F. 2016. Transcriptome response mediated by cold stress in *Lotus japonicus*. *Frontiers in Plant Science* 7:1–16.

Campestre, M.P., Castagno, L.N., Estrella, M.J., Ruiz, O.A. 2016. *Lotus japonicus* plants of the Gifu B-129 ecotype subjected to alkaline stress improve their Fe^{2+} bioavailability through inoculation with *Pantoea eucalypti* M91. *Journal of Plant Physiology* 192:47–55.

Carillo, P., Annunziata, M.G., Pontecorvo, G., Fuggi, A., Woodrow, P. 2011. Salinity stress and salt tolerance. In *Abiotic Stress in Plants: Mechanisms and Adaptations*. A. Shanker (ed.). InTech, Rijeka, Croatia, pp. 21–38.

Carillo, P., Mastrolonardo, G., Nacca, F., Parisi, D., Verlotta, A., Fuggi, A. 2008. Nitrogen metabolism in durum wheat under salinity: Accumulation of proline and glycine betaine. *Functional Plant Biology* 35:412–426.

Chaves, M.M. 1991. Effects of water deficits on carbon assimilation. *Journal of Experimental Botany* 42:1–16.

Chaves, M.M., Costa, J.M., Zarrouka, O., Pinheiro, C., Lopes, C.M., Pereira, J.S. 2016. Controlling stomatal aperture in semi-arid regions: The dilemma of saving water or being cool? *Plant Science* 251:54–64.

Chaves, M.M., Flexas, J., Pinheiro, C. 2009. Photosynthesis under drought and salt stress: Regulation mechanisms from whole plant to cell. *Annals of Botany* 103:551–560.

Chaves, M.M., Maroco, J.P., Pereira, J.S. 2003. Understanding plant responses to drought from genes to the whole plant. *Functional Plant Biology* 30:239–264.

Chen, H., He, H., Yu, D. 2011. Over expression of a novel soybean gene modulating Na^+ and K^+ transport enhances salt tolerance in transgenic tobacco plants. *Physiologia Plantarum* 141:11–18.

Chen, L.J., Xiang, H.Z., Miao, Y., Zhang, L., Guo, Z.F., Zhao, X.H., Lin, J.W., Li, T.L. 2014. An overview of cold resistance in plants. *Journal of Agronomy and Crop Science* 200:237–245.

Chen, T., Zhang, L., Shang, H., Liu, S., Peng, J., Gong, W., Shi, Y., et al. 2016. iTRAQ-based quantitative proteomic analysis of cotton roots and leaves reveals pathways associated with salt stress. *PLoS One* 11(2):e0148487.

Cheng, L., Gao, X., Li, S., Shi, M., Javeed, H., Jing, X., Yang, G., He, G. 2010. Proteomic analysis of soybean [*Glycine max* (L.) Meer.] seeds during imbibition at chilling temperature. *Molecular Breeding* 26:1–17.

Comstok, J. 2002. Hydraulic and chemical signaling in the control of stomatal conductance and transpiration. *Journal of Experimental Botany* 53:195–200.

Dametto, A., Sperotto R.A., Adamski, J.M., Blasi, É.A.R., Cargneluttie, D., De Oliveira, L.F.V., Ricachenevsky, F.K., et al. 2015. Cold tolerance in rice germinating seeds revealed by deep RNAseq analysis of contrasting indica genotypes. *Plant Science* 238:1–12.

Demming-Adams, B., Adams, W.W. 1996. The role of xanthophylls cycle carotenoids in the protection of photosynthesis. *Trends in Plant Science* 1:21–26.

Diao, Q., Song, Y., Shi, D., Qi, H. 2017. Interaction of polyamines, abscisic acid, nitric oxide, and hydrogen peroxide under chilling stress in tomato (*Lycopersicon esculentum* mill.) seedlings. *Frontiers in Plant Science* 8:203.

Echeverria, M., Scambato, A.A., Sannazzaro, A.I., Maiale, S., Ruiz, O.A., Menéndez, A.B. 2008. Phenotypic plasticity with respect to salt stress response by *Lotus glaber*: The role of its AM fungal and rhizobia symbionts. *Mycorrhiza* 18:317–329.

Eissenstat, D.M., Wells, C.E., Yanai, R.D., Whitbeck, J.L. 2000. Building roots in a changing environment: Implication for root longevity. *New Phytology* 147:33–42.

ElSayed, A.I., Rafudeen, M.S., Golldack, D. 2014. Physiological aspects of raffinose family oligosaccharides in plants: Protection against abiotic stress. *Plant Biology* 16:1–8.

Espasandin, F., Calzadilla, P., Maiale, S., Ruiz, O., Sansberro, P. 2018. Overexpression of the arginine decarboxylase gene improves tolerance to salt stress in *Lotus tenuis* plants. *Journal of Plant Growth Regulation* 37(1):156–165.

Essa, T.A. 2002. Effect of salinity stress on growth and nutrient composition of three soybeans (*Glycine max* L. Merrill) cultivars. *Journal of Agronomy and Crop Science* 188:86–93.

FAO: Land and Water Division (NRL). 2013. http://www.fao.org/ag/agl/agll/spush/intro.htm. Accessed 26 August 2013.

FAO. 1996. *The Production Yearbook*. Rome, Italy.

FAO. 2009. www.fao.org/askfao/topicsList.do?mainAreaId=20263.

Flemetakis, E., Efrose, R.C., Ott, T., Stedel, C., Aivalakis, G., Udvardi, M.K., Katinakis, P. 2006. Spatial and temporal organization of sucrose metabolism in *Lotus japonicus* nitrogen-fixing nodules suggests a role for the elusive alkaline/neutral invertase. *Plant Molecular Biology* 62:53–69.

Flexas, J., Bota, J., Loreto, F., Cornic, G., Sharkey, T.D. 2004. Diffusive and metabolic limitations to photosynthesis under drought and salinity in C3 plants. *Plant Biology (Stuttgart)* 6(3):269–79.

Flexas, J., Ribas-Carbó, M., Bota, J., Galmés, J., Henkle, M., Martínez-Cañellas, S. 2006. Decreased Rubisco activity during water stress is not induced by decreased relative water content but related to conditions of low stomatal conductance and chloroplast CO_2 concentration. *New Phytologist* 172:73–82.

Flowers, T.J., Yeo, A.R. 1986. Ion relations of plant under drought and salinity. *Australian Journal of Plant Physiology* 13:75–91.

Foyer, H.C., Vanacker, H., Gomez, L.D., Harbinson, J. 2002. Regulation of photosynthesis and antioxidant metabolism in maize leaves at optimal and chilling temperatures: Review. *Plant Physiology and Biochemistry* 40:659–668.

Fricke, W., Akhiyarova, G., Wei, W., Alexandersson, E., Miller, A., Kjellbom, P.O., Richardson, A., et al. 2006. The short-term growth response to salt of the developing barley leaf. *Journal of Experimental Botany* 57:1079–1095.

Fuad-Hassan, A., Tardieu, F., Turc, O. 2008. Drought-induced changes in anthesis-silking interval are related to silk expansion: A spatio-temporal growth analysis in maize plants subjected to soil water deficit. *Plant, Cell and Environment* 31:1349–1360.

Garg, A.K., Kim, J.K., Owens, T.G., Ranwala, A.P., Choi, Y.D., Kochian, L.V., Wu, R.J. 2002. Trehalose accumulation in rice plants confers high tolerance levels to different abiotic stresses. *Proceedings of the National Academy of Sciences* 99:15898–15903.

Gárriz, A., Dalmasso, M.C., Marina, M., Rivas, E.I., Ruiz, O.A., Pieckenstain, F.L. 2003. Polyamine metabolism during the germination of *Sclerotinia sclerotiorum* ascospores and its relation with host infection. *New Phytologist* 161:847–854.

Gill, S.S., Tuteja, N. 2010. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. *Plant Physiology and Biochemistry* 48:909–930.

Gorham, J., Wyn Jones, R.G., Bristol, A. 1990. Partial characterization of the trait for enhanced K+-Na+ discrimination in the D genome of wheat. *Planta* 180:590–597.

Greenway, H., Munns, R. 1980. Mechanisms of salt tolerance in nonhalophytes. *Annual Review of Plant Physiology* 31:149–190.

Guo, W.X., Mass, S.J., Bronson, K.F. 2012. Relationship between cotton yield and soil electrical conductivity, topography, and Landsat imagery. *Precision Agronomy* 13:678–692.

Guy, Ch., Huber, J.L.A., Huber, S.C. 1992. Sucrose phosphate synthase and sucrose accumulation at low temperature. *Plant Physiology* 100:502–508.

Hahn, M., Walbot, V. 1989. Effects of cold-treatment on protein synthesis and mRNA levels in rice leaves. *Plant Physiology* 91:930–938.

Hashimoto, M., Komatsu, S. 2007. Proteomic analysis of rice seedlings during cold stress. *Proteomics Journal* 7:1293–1302.

Henry, C., Bledsoe, S.W., Griffiths, C.A., Kollman, A., Paul, M.J., Sakr, S., Lagrimini, M. 2015. Differential role for trehalose metabolism in salt-stressed maize. *Plant Physiology* 169:1072–1089.

Huner, N.P.A., Öquist, G., Sarhan, F. 1998. Energy balance and acclimation to light and cold. *Trends in Plant Science* 3:224–230.

Iba, K. 2002. Acclimative response to temperature stress in higher plants: Approaches of gene engineering for temperature tolerance. *Annual Review Plant Biology* 53:225–245.

Intergovernmental Panel on Climate Change. 2007. http://www.ipcc.ch. Accessed 25 October 2007.

Ishitani, M., Xiong, L., Stevenson, B., Zhu, J.K. 1997. Genetic analysis of osmotic and cold stress signal transduction in *Arabidopsis*: Interactions and convergence of abscisic acid-dependent and abscisic acid-independent pathways. *The Plant Cell* 9:1935–1949.

Janska, P., Marsik, P., Zelenkova S., Ovesna, J. 2010. Cold stress and acclimation: What is important for metabolic adjustment?. *Plant Biology* 12:395–405.

Ji, H., Pardo, J.M., Batelli, G., Van Oosten, M.J., Bressan, R.A., Li, X. 2013. The salt overly sensitive (SOS) pathway: Established and emerging roles. *Molecular Plant* 6:275–286.

Jiang, M., Zhang, J. 2002. Water stress-induced abscisic acid accumulation triggers the increased generation of reactive oxygen species and up-regulates the activities of antioxidant enzymes in maize leaves. *Journal of Experimental Botany* 53:2401–2410.

Jones, H.G. 2007. Monitoring plant and soil water status: Established and novel methods revisited and their relevance to studies of drought tolerance. *Journal of Experimental Botany* 58:119–130.

Kaiser, W.M. 1987. Effect of water deficit on photosynthetic capacity. *Physiologia Plantarum* 71:142–149.

Kirkbride, J.H. 2006. The scientific name of narrow-leaf trefoil. *Crop Science* 46:2169–2170.

Kobayashi, F., Maeta, E., Terashima, A., Kawaura, K., Ogihara, Y., Takumi, S. 2008. Development of abiotic stress tolerance via bZIP-type transcription factor LIP19 in common wheat. *Journal of Experimental Botany* 59:891–905.

Läuchli, A. 1984. Salt exclusion: An adaptation of legumes for crops and pastures under saline conditions. In *Salinity Tolerance in Plants: Strategies for Crop Improvement.* R.C. Staples, G.H. Toennissen (eds.). Wiley, New York, pp. 171–187.

Lawlor, D.W., Cornic, G. 2002. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant, Cell and Environment* 25:275–294.

León, P., Sheen, J. 2003. Sugar and hormone connections. *Trends in Plant Science* 8:110–116.

Li, Z., Wakao, S., Fischer, B., Niyogi, K. 2009. Sensing and responding to excess light. *Annual Review of Plant Biology* 60:239–60.

López-Gómez, M., Hidalgo-Castellanos, J., Iribarne, C., Lluch, C. 2014. Proline accumulation has prevalence over polyamines in nodules of *Medicago sativa* in symbiosis with *Sinorhizobium meliloti* during the initial response to salinity. *Plant and Soil* 374:149–159.

Lu, Z.M., Cheng, J.W., Percy, R.G., Zeiger, E. 1997. Photosynthetic rate, stomatal conductance and leaf area in two cotton species (*Gossypium barbadense* and *Gossypium hirsutum*) and their relation with heat resistance and yield. *Australian Journal of Plant Physiology* 24:693–700.

Lunn, J.E., Delorge, I., Figueroa, C.M., Van Dijck, P., Stitt, M. 2014. Trehalose metabolism in plants. *The Plant Journal* 79:544–567.

Lyons, J.M. 1973. Chilling injury in plants. *Annual Review Plant Physiology* 24:445–466.

Marina, M., Maiale, S., Rossi, F., Romero, M., Rivas, M., Gárriz, A., Ruiz, O., Pieckenstain, F. 2008. Apoplastic polyamine oxidation plays different roles in local responses of tobacco to infection by the necrotrophic fungus *Sclerotinia sclerotiorum* and the biotrophic bacterium *Pseudomonas*. *Plant Physiology* 147:2164–2178.

Marraccini, P., Vinecky, F., Alves, G., Ramos, H., Elbet, S., Vieira, N., Carneiro, F., et al. 2012. Differentially expressed genes and proteins upon drought acclimation in tolerant and sensitive genotypes of *Coffea canephora*. *Journal of Experimental Botany* 63:4191–4212.

Maruyama, K., Urano, K., Yoshiwara, K., Morishita, Y., Sakurai, N., Suzuki, H., Kojima, M., et al. 2014. Integrated analysis of the effects of cold and dehydration on rice metabolites, phytohormones, and gene transcripts. *Plant Physiology* 164:1759–1771.

Mazzanti, A., Darwich, N.A., Cheppi, C., Sarlangue, H. 1986. Persistencia de pasturas cultivadas en zonas ganaderas de la Pcia. de Buenos Aires. *Revista Argentina de Producción Animal* 6:65.

McDonald, A.J.S., Davies, W.J. 1996. Keeping in touch: Responses of the whole plant to deficits in water and nitrogen supply. *Advances in Botanical Research* 22:229–300.

Meloni, D.A., Oliva, M.A., Ruiz, H.A., Martinez, C.A. 2001. Contribution of proline and inorganic solutes to osmotic adjustment in cotton under salt stress. *Journal of Plant Nutrition* 24:599–612.

Miller, G., Suzuki, N., Ciftci-Yilmaz, S., Mittler, R. 2010. Reactive oxygen species homeostasis and signaling during drought and salinity stresses. *Plant, Cell and Environment* 33:453–467.

Mittova, V., Tal, M., Volokita, M., Guy, M. 2003. Up-regulation of the leaf mitochondrial and peroxisomal antioxidative systems in response to salt-induced oxidative stress in the wild salt-tolerant tomato species (*Lycopersicon pennellii*). *Plant Cell and Environment* 26:845–856.

Munns, R. 1988. Effect of high external NaCl concentrations of ion transport within the shoot of *Lupinus albus*. I. Ions in xylem sap. *Plant, Cell and Environment* 11:283–289.

Munns, R. 2002. Comparative physiology of salt and water stress. *Plant, Cell and Environment* 25:239–250.

Munns, R., James, R.A., Läuchli, A. 2006. Approaches to increasing the salt tolerance of wheat and other cereals. *Journal of Experimental Botany* 57:1025–1043.

Munns, R., Schachtman, D.P., Condon, A.G. 1995. The significance of a two-phase growth response to salinity in wheat and barley. *Australian Journal of Plant Physiology* 22:561–569.

Nelson, N., Yocum, C.F. 2006. Structure and function of photosystems I and II. *Annual Review of Plant Biology* 57:521–565.

Nobel, P. 2009. *Physicochemical and Environmental Plant Physiology.* 4th edition. Elsevier, Los Angeles, CA

Noctor, G., Veljovic-Jovanovic, S., Driscoll, S., Novitskaya, L., Foyer, C.H. 2002. Drought and oxidative load in the leaves of C3 plants: A predominant role for photorespiration? *Annals of Botany* 89:841–850.

Parvaiz, A., Satyawati, S. 2008. Salt stress and phyto-biochemical responses of plants: A review. *Plant Soil and Environment* 54:89–99.

Passioura, J. 2007. The drought environment: Physical, biological and agricultural perspectives. *Journal of Experimental Botany* 58:113–117.

Passioura, J.B. 2010. Scaling up: The essence of effective agricultural research. *Functional Plant Biology* 37:585–591.

Pastenes, C., Pimentel, P., Lillo, J. 2004. Leaf movements and photoinhibition in relation to water stress in field-grown beans. *Journal of Experimental Botany* 56:425–433.

Paz, R.C., Reinoso, H., Espasandin, F.D., Gonzalez Antivilo, F.A., Sansberro, P.A., Rocco, R.A., Ruiz, O.A., Menéndez, A.B. 2014. Alkaline, saline and mixed saline–alkaline stresses induce physiological and morph o-anatomical changes in *Lotus tenuis* shoots. *Plant Biology* 16:1042–1049.

Peoples, T.R., Koch, D.W., Smith, S.C. 1978. Relationship between chloroplast membrane fatty acid composition and photosynthetic response to a chilling temperature in four alfalfa cultivars. *Plant Physiology* 61:472–473.

Perdomo, J.A., Capó-Bauçà, S., Carmo-Silva, E., Galmés, J. 2017. Rubisco and rubisco activase play an important role in the biochemical limitations of photosynthesis in rice, wheat, and maize under high temperature and water deficit. *Frontiers in Plant Science* 8:1–15.

Pinheiro, C., Chaves, M.M. 2010. Photosynthesis and drought: can we make metabolic connections from available data? *Journal of Experimental Botany* 62:869–882.

Quan, W., Liu, X., Wang, H., Chan, Z. 2016. Comparative physiological and transcriptional analyses of two contrasting drought tolerant alfalfa varieties. *Frontiers in Plant Science* 6:1256–1272.

Rahman, Md. A., Yong-Goo, K., Iftekhar, A., Liu, G-Sh., Hyoshin, L., Jeung Joo, L., Byung-Hyun, L. 2016. Proteome analysis of alfalfa roots in response to water deficit stress. *Journal of Integrative Agriculture* 15:1275–1285.

Regier, N., Streb, S., Cocozza, C., Schaub, M., Cherubini, P., Zeeman, S.C., Frey, B. 2009. Drought tolerance of two black poplar (*Populus nigra* L.) clones: Contribution of carbohydrates and oxidative stress defense. *Plant, Cell and Environment* 32:1724–1736.

Rinalducci, S., Egidi, M.G., Karimzadeh, G., Jazii, F.R., Zolla, L. 2011. Proteomic analysis of a spring wheat cultivar in response to prolonged cold stress. *Electrophoresis* 32:1807–1818.

Rodziewicz, P., Swarcewicz, B., Chmielewska, K., Wojakowska, A., Stobiecki, M. 2014. Influence of abiotic stresses on plant proteome and metabolome changes. *Acta Physiologiae Plantarum* 36:1–19.

Sage, R.F. 2004. The evolution of C4 photosynthesis. *New Phytology* 161:341–370.

Sage, R.F., Way, D.A., Kubien, D.S. 2008. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Journal of Experimental Botany* 59:1581–1595.

Saito, M., Yoshida, M. 2011. Expression analysis of the gene family associated with raffinose accumulation in rice seedlings under cold stress. *Journal of Plant Physiology* 168:2268–2271.

Savitch, L.V., Harney, T., Huner, N.P.A. 2000. Sucrose metabolism in spring and winter wheat in response to high irradiance, cold stress and cold acclimation. *Physiologia Plantarum* 108:270–278.

Seki, M., Kamei, A., Satou, M., Sakurai, T., Fujita, M., Oono, Y., Yamaguchi-Zhinozaki, K., Zhinozaki, K. 2003. Transcriptome analysis in abiotic stress conditions in higher plants. *Topics in Current Genetics* 4:271–295.

Setter, T.L., Flannigan, B.A. 2001. Water deficit inhibits cell division and expression of transcripts involved in cell proliferation and endoreduplication in maize endosperm. *Journal of Experimental Botany* 52:1401–1408.

Sharp, R.E. 2002. Interaction with ethylene: Changing views on the role of abscisic acid in root and shoot growth responses to water stress. *Plant, Cell and Environment* 25:211–222.

Shi, H. 2007. Integration of Ca^{2+} in plant drought and salt stress signal transduction pathways. In *Advances in Molecular Breeding toward Drought and Salt tolerant Crops*. M.A. Jenks, P.M. Hasegawa, S.M. Jain (eds.). Springer, Dordrecht, the Netherlands, pp. 141–182.

Shinozaki, K., Yamaguchi-Shinozaki, K. 2007. Gene networks involved in drought stress response and tolerance. *Journal of Experimental Botany* 58:221–227.

Signorelli, S., Corpas, F.J., Borsani, O., Barroso, J.B., Monza, J. 2013. Water stress induces a differential and spatially distributed nitro-oxidative stress response in roots and leaves of *Lotus japonicus*. *Plant Science* 201–202:137–146.

Silveira, A.G., Carvalho, F.E.L. 2016. Proteomics, photosynthesis and salt resistance in crops: An integrative view. *Journal of Proteomics* 143:24–35.

Singleton, P.W., Bohlool, B.B. 1983. The effect of salinity on the functional components of the soybean *Rhizobium japonicum* symbiosis. *Crop Science* 23:815–818.

Song, L., Jiang, L., Chen, Y., Shu, Y., Bai, Y., Guo, C. 2016a. Deep-sequencing transcriptome analysis of field-grown *Medicago sativa* L. crown buds acclimated to freezing stress. *Functional and Integrative Genomics* 16(5):495–511.

Song, L., Prince, S., Valliyodan, B., Joshi, T., Maldonado dos Santos, J.V., Wang, J., Lin, L et al. 2016b. Genome-wide transcriptome analysis of soybean primary root under varying water deficit conditions. *BMC Genomics* 15:57.

Sun, C.X., Gao, X.X., Li, M.Q., Fu, J.Q., Zhang, Y.L. 2016. Plastic responses in the metabolome and functional traits of maize plants to temperature variations. *Plant Biology* 18:249–261.

Suzuki, K., Aoki, N., Matsumura, H., Okamura, M., Ohsugi, R., Shimono, H. 2015. Cooling water before panicle initiation increases chilling-induced male sterility and disables chilling-induced expression of genes encoding OsFKBP65 and heat shock proteins in rice spikelets. *Plant, Cell and Environment* 38:1255–1274.

Suzuki, N., Mittler, R. 2006. Reactive oxygen species and temperature stresses: A delicate balance between signaling and destruction. *Physiologia Plantarum* 126:45–51.

Taiz, L., Zeiger, E. 2003. *Plant Physiology.* 3rd edition. Sinauer Associates Inc., Sunderland, MA.

Tang, X., Mu, X., Shao, H., Wang, H., Brestic, M. 2014. Global plant-responding mechanisms to salt stress: Physiological and molecular levels and implications in biotechnology. *Critical Reviews in Biotechnology*. Early Online: 1–13.

Tardieu, F., Simonneau, T. 1998. Variability among species of stomatal control under fluctuating soil water status and evaporative demand: Modelling isohydric and anisohydric behaviors. *Journal of Experimental Botany* 49:419–432.

Tarkowski, Ł.P., Van den Ende, W. 2015. Cold tolerance triggered by soluble sugars: A multifaceted countermeasure. *Frontiers in Plant Science* 6:1–7.

Taylor, S.H., Ripley, B.S., Woodward, F.I., Osborne, C.P. 2011. Drought limitation of photosynthesis differs between C3 and C4 grass species in a comparative experiment. *Plant, Cell and Environment* 34:65–75.

Tezara, W., Mitchell, V.J., Driscoll, S.D., Lawlor, D.W. 1999. Water stress inhibits plant photosynthesis by decreasing coupling factor and ATP. *Nature* 401:914–917.

Tian, X., Liu, Y., Huang, Z., Duan, H., Tong, J., He, X., Gu, W., Ma, H., Xiao, L. 2015. Comparative proteomic analysis of seedling leaves of cold-tolerant and -sensitive spring soybean cultivars. *Molecular Biology Reports* 42:581–601.

Turner, N.C., Jones, M.M. 1980. Turgor maintenance by osmotic adjustment: A review and evaluation. In *Adaptation of plants to water and high temperature stress*. N.C. Turner, P.J. Kramer (eds.). Wiley InterScience, New York, pp. 87–103.

Tuteja, N., Gill, S., Tuteja, R. 2011. Plant responses to abiotic stresses: Shedding light on salt, drought, cold, and heavy metal stress. In *Omics and Plant Stress Tolerance*. N. Tuteja, S. Gill, R. Tuteja (eds.). Bentham Science Publisher, Sharjah, UAE, pp. 39–64.

UNESCO Water Portal. 2007. http://www.unesco.org/water. Accessed 25.

Upchurch, R.G. 2008. Fatty acid unsaturation, mobilization, and regulation in the response of plants to stress. *Biotechnology Letters* 30:967–977.

USSL STAFF. 1954. Diagnosis and improvement of saline and alkali soils. In *Agriculture Handbook 60*. L.A. Richards (ed.). USDA, Washington, DC (Reprinted 1969).

Vargas, W.A., Pontis, H.G., Salerno, G.L. 2007. Differential expression of alkaline and neutral invertases in response to environmental stresses: Characterization of an alkaline isoform as a stress-response enzyme in wheat leaves. *Planta* 226:1535–1545.

Wang, X., Shan, X., Wu, Y., Su, S., Li, S., Liu, H., Han, J., Xue, C., Yuan, Y. 2016. iTRAQ-based quantitative proteomic analysis reveals new metabolic pathways responding to chilling stress in maize seedlings. *Journal of Proteomics* 146:14–24.

Westgate, M.E., Boyer, J.S. 1985. Carbohydrate reserves and reproductive development at low leaf water potentials in maize. *Crop Science* 25:762–769.

Wilkinson, S., Davies, J. 2002. ABA-based chemical signaling: The coordination of responses to stress in plants. *Plant, Cell and Environment* 25:195–210.

Willemot, C., Hope, H.J., Williams, R.J., Michaud, R. 1977. Changes in fatty acid composition of winter wheat during frost hardening. *Cryobiology* 14:87–93.

Wingler, A., Lea, P.J., Quick, W.P., Leegood, R.C. 2000. Photorespiration: Metabolic pathways and their role in stress protection. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 355:1517–1529.

Wu, G., Zhou, Z., Chen, P., Tang, X., Shao, H., Wang, H. 2014. Comparative ecophysiological study of salt stress for wild and cultivated soybean species from the Yellow River Delta, China. *The Scientific World Journal*. Article ID 651745.

Xiong, L. 2007. Abscisic acid in plant response and adaptation to drought and salt stress. In *Advances in Molecular Breeding toward Drought and Salt Tolerant Crops*. M. Jenks, P. Hasegawa, S. Jain (eds.). Springer, Dordrecht, the Netherlands, pp. 193–221.

Xiong, L., Ishitani, M. 2006. Stress signal transduction: Components, pathways and network integration. In *Abiotic Stress Tolerance in Plants*. A.K. Rai, T. Takabe (eds.). Springer, Dordrecht, the Netherlands, pp. 3–29.

Xiong, L., Schumaker, K.S., Zhu, J.K. 2002. Cell signaling during cold, drought, and salt stress. *The Plant Cell* 14:S165–S183.

Xiong, L., Zhu, J.K. 2002. Molecular and genetic aspects of plant responses to osmotic stress. *Plant, Cell and Environment* 25:131–139.

Xu, J., Li, Y., Sun, J., Du, L., Zhang, Y., Yu, Q., Liu, X. 2013. Comparative physiological and proteomic response to abrupt low temperature stress between two winter wheat cultivars differing in low temperature tolerance. *Plant Biology* 15:292–303.

Yadav, S., Irfan, M., Ahmad, A., Hayat, S. 2011. Causes of salinity and plant manifestations to salt stress: A review. *Journal of Environmental Biology* 32:667–685.

Yan, J., Wang, B., Jiang, Y., Cheng, L., Wu, T. 2013. GmFNSII-controlled soybean flavone metabolism responds to abiotic stresses and regulates plant salt tolerance. *Plant and Cell Physiology* 55:74–86.

Yan, W., Zhong, Y., Shangguan, Z. 2017. Rapid response of the carbon balance strategy in *Robinia pseudoacacia* and *Amorpha fruticosa* to recurrent drought. *Environmental and Experimental Botany* 138:46–56.

Yeo, A.R., Lee, K.S., Izard, P., Boursier, P.J., Flowers, T.J. 1991. Short- and long-term effects of salinity on leaf growth in rice (*Oryza sativa* L.). *Journal of Experimental Botany* 42:881–889.

Yin, Y., Yang, R., Han, Y., Gu, Z. 2015. Comparative proteomic and physiological analyses reveal the protective effect of exogenous calcium on the germinating soybean response to salt stress. *Journal of Proteomics* 113:110–126.

Yokoi, S., Quintero, F.J., Cubero, B., Ruiz, M.T., Bressan, R.A., Hasegawa, P.M., Pardo, J.M. 2002. Differential expression and function of *Arabidopsis thaliana* NHX Na^+/H^+ antiporters in the salt stress response. *Plant Journal* 30:529–539.

Zhang, H., Han, B., Wang, T., Chen, S., Li, H., Zhang, Y., Dai, S. 2012. Mechanisms of plant salt response: Insights from proteomics. *Journal of Proteome Research* 11:49–67.

Zhang, L., Ma, H., Chen, T., Pen, J., Yu, S., Zhao, X. 2014. Morphological and physiological responses of cotton (*Gossypium hirsutum* L.) plant to salinity. *PLoS One* 9:e112807.

Zheng, Q., Liu, J., Liu, R., Wu, H., Jiang, C., Wang, C., Guan, Y. 2016. Temporal and spatial distributions of sodium and polyamines regulated by brassinosteroids in enhancing tomato salt resistance. *Plant Soil* 400:147–164.

Zhou, F., Sosa, J., Feldmann, K.A. 2007. High throughput approaches for the identification of salt tolerance genes in plants. In *Advances in Molecular Breeding toward Drought and Salt Tolerant Crops*. M.A. Jenks, P.M. Hasegawa, S.M Jain. (eds.), Springer, Dordrecht, the Netherlands, pp. 359–379.

Zhu, J.K. 2003. Regulation of ion homeostasis under salt stress. *Current Opinion in Plant Biology* 6:441–445.

Zhu, S.-Q., Yu, C.-M., Liu, X.-Y., Ji, B.-H., Jiao, D.-M. 2007. Changes in unsaturated levels of fatty acids in thylakoid PSII membrane lipids during chilling-induced resistance in rice. *Journal of Integrative Plant Biology* 49:463–471.

Zhuo, Ch., Wang, T., Lu, S., Zhao, Y., Li, X., Guo, Z. 2013. A cold responsive galactinol synthase gene from *Medicago falcata* (MfGolS1) is induced by myo-inositol and confers multiple tolerances to abiotic stresses. *Physiologia Plantarum* 149:67–78.

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Abogadallah, G. M. 2010. Antioxidative defense under salt stress. Plant Signaling and Behavior 5(4):369374.

Aguirrezbal, L. , Bouchier-Combaud, S. , Radziejwoski, A. , Dauzat, M. , Cookson, S.J. , Granier, G. 2006. Plasticity to soil water deficit in Arabidopsis thaliana: Dissection of leaf development into underlying growth dynamic and cellular variables reveals invisible phenotypes. Plant, Cell and Environment 29:22162227.

Ahmads, S. , Khan, N. , Iqbal, M.Z. 2002. Salt tolerance of cotton (Gossypium hirsutum L.). Asian Journal of Plant Science 1:715719.

Airaki, M. , Snchez-Moreno, L. , Leterrier, M. , Barroso, J.B. , Palma, J.M. , Corpas, F.J. 2011. Detection and quantification of S-nitrosoglutathione (GSNO) in pepper (Capsicum annuum L.) plant organs by LC-ES/MS. Plant and Cell Physiology 52:20062015.

Annunziata, M.G. , Ciarmiello, L.F. , Woodrow, P. , Maximova, E. , Fuggi, A. , Carillo, P. 2017. Durum wheat roots adapt to salinity remodeling the cellular content of nitrogen metabolites and sucrose. Frontiers in Plant Science 7, Article 2035.

Arasimowicz-Jelonek, M. , Floryszak-Wieczorek, J. , Kubis, J. 2009. Interaction between polyamine and nitric oxide signaling in adaptive responses to drought in cucumber. Journal of Plant Growth Regulation 28:177186.

Arajo, S.S. , Beebe, S. , Crespi, M. , Delbreil, B. , Gonzlez, E.M. , Gruber, V. , Lejeune-Henaut, I. , et al. 2015. Abiotic stress responses in legume s: Strategies used to cope with environmental challenges. Critical Reviews in Plant Science 34:237280.

Araus, J.L. , Serret, M.D. , Edmeades, G.O. 2012. Phenotyping maize for adaptation to drought. Frontiers in Physiology 3:305.

Ashraf, M. 2009. Biotechnological approach of improving plant salt tolerance using antioxidants as markers. Biotechnology Advance 27:8493.

Azcn-Bieto, J. , Taln, M. 2008. Fundamentos de Fisiologa Vegetal. 2nd edition. Interamericana-McGraw-Hill, Madrid.

Baghel, L. , Kataria, S. , Guruprasad, K.N. 2016. Static magnetic field treatment of seeds improves carbon and nitrogen metabolism under salinity stress in soybean. Bioelectromagnetics 37:455470.

Baker, N. 2008. Chlorophyll fluorescence: A probe of photosynthesis in vivo. Annual Review of Plant Biology 59:89113.

Bnziger, M. , Cooper, M.E. 2001. Breeding for low input conditions and consequences for participatory plant breeding-examples from tropical maize and wheat. Euphytica 122:503519.

Bartlett, M.K. , Scoffoni, C. , Sack, L. 2012. The determinants of leaf turgor loss point and prediction of drought tolerance of species and biomes: A global meta-analysis. Ecology Letters 15:393405.

Beck, E.H. , Fettig, S. , Knake, C. , Harting, K. , Bhattarai, T. 2007. Specific and unspecific responses of plants to cold and drought stress. Journal of Biosciences 32:501510.

Bell, L.W. , Williams, A.H. , Ryan, M.H. , Ewing, M.A. 2007. Water relations and adaptations to increasing water deficit in three perennial legumes, Medicago sativa, Dorycnium hirsutum and Dorycnium rectum. Plant and Soil 290:231243.

Blum, A. 2005. Drought resistance, water-use efficiency, and yield potential: Are they compatible, dissonant, or mutually exclusive? Australian Journal of Agriculture Research 56:11591168.

Blum, A. 2016. Osmotic adjustment is a prime drought stress adaptive engine in support of plant production. Plant, Cell and Environment 40:410.

Bohnert, H.J. , Jensen, R.G. 1996. Strategies for engineering water-stress tolerance in plants. Trends Biotechnology 14:8997.

Boyer, J.S. 2010. Drought decision making. Journal of Experimental Botany 61:34933497.

Bray, E.A. 2007. Molecular and physiological responses to water-deficit stress. In Advances in Molecular Breeding toward Drought and Salt Tolerant Crops. M.A. Jenks et al. (eds.). Springer, Dordrecht, the Netherlands, pp. 121140.

Brunner, I. , Herzog, C. , Dawes, M.A. , Arend, M. , Sperisen, C. 2015. How tree roots respond to drought. Frontiers in Plant Science 6:547.

Busk, K. , Pages, M. 1998. Regulation of abscisic acid-induced transcription. Plant Molecular Biology 37:425435.

Calzadilla, P. , Maiale, S. , Ruiz, O. , Escaray, F. 2016. Transcriptome response mediated by cold stress in Lotus japonicus. Frontiers in Plant Science 7:116.

Campestre, M.P. , Castagno, L.N. , Estrella, M.J. , Ruiz, O.A. 2016. Lotus japonicus plants of the Gifu B-129 ecotype subjected to alkaline stress improve their Fe2+ bioavailability through inoculation with Pantoea eucalypti M91. Journal of Plant Physiology 192:4755.

Carillo, P. , Annunziata, M.G. , Pontecorvo, G. , Fuggi, A. , Woodrow, P. 2011. Salinity stress and salt tolerance. In Abiotic Stress in Plants: Mechanisms and Adaptations. A. Shanker (ed.). InTech, Rijeka, Croatia, pp. 2138.

Carillo, P. , Mastrolonardo, G. , Nacca, F. , Parisi, D. , Verlotta, A. , Fuggi, A. 2008. Nitrogen metabolism in durum wheat under salinity: Accumulation of proline and glycine betaine. Functional Plant Biology 35:412426.

Chaves, M.M. 1991. Effects of water decits on carbon assimilation. Journal of Experimental Botany 42:116.

Chaves, M.M. , Costa, J.M. , Zarrouka, O. , Pinheiro, C. , Lopes, C.M. , Pereira, J.S. 2016. Controlling stomatal aperture in semi-arid regions: The dilemma of saving water or being cool? Plant Science 251:5464.

Chaves, M.M. , Flexas, J. , Pinheiro, C. 2009. Photosynthesis under drought and salt stress: Regulation mechanisms from whole plant to cell. Annals of Botany 103:551560.

Chaves, M.M. , Maroco, J.P. , Pereira, J.S. 2003. Understanding plant responses to drought from genes to the whole plant. Functional Plant Biology 30:239264.

Chen, H. , He, H. , Yu, D. 2011. Over expression of a novel soybean gene modulating Na+ and K+ transport enhances salt tolerance in transgenic tobacco plants. Physiologia Plantarum 141:1118.

Chen, L.J. , Xiang, H.Z. , Miao, Y. , Zhang, L. , Guo, Z.F. , Zhao, X.H. , Lin, J.W. , Li, T.L. 2014. An overview of cold resistance in plants. Journal of Agronomy and Crop Science 200:237245.

Chen, T. , Zhang, L. , Shang, H. , Liu, S. , Peng, J. , Gong, W. , Shi, Y. , et al. 2016. iTRAQ-based quantitative proteomic analysis of cotton roots and leaves reveals pathways associated with salt stress. PLoS One 11(2):e0148487.

Cheng, L. , Gao, X. , Li, S. , Shi, M. , Javeed, H. , Jing, X. , Yang, G. , He, G. 2010. Proteomic analysis of soybean [Glycine max (L.) Meer.] seeds during imbibition at chilling temperature. Molecular Breeding 26:117.

17 Comstok, J. 2002. Hydraulic and chemical signaling in the control of stomatal conductance and transpiration. Journal of Experimental Botany 53:195200.

Dametto, A. , Sperotto R.A. , Adamski, J.M. , Blasi, .A.R. , Cargneluttie, D. , De Oliveira, L.F.V. , Ricachenevsky, F.K. , et al. 2015. Cold tolerance in rice germinating seeds revealed by deep RNAseq analysis of contrasting indica genotypes. Plant Science 238:112.

Demming-Adams, B. , Adams, W.W. 1996. The role of xanthophylls cycle carotenoids in the protection of photosynthesis. Trends in Plant Science 1:2126.

Diao, Q. , Song, Y. , Shi, D. , Qi, H. 2017. Interaction of polyamines, abscisic acid, nitric oxide, and hydrogen peroxide under chilling stress in tomato (Lycopersicon esculentum mill.) seedlings. Frontiers in Plant Science 8:203.

Echeverria, M. , Scambato, A.A. , Sannazzaro, A.I. , Maiale, S. , Ruiz, O.A. , Menndez, A.B. 2008. Phenotypic plasticity with respect to salt stress response by Lotus glaber: The role of its AM fungal and rhizobia symbionts. Mycorrhiza 18:317329.

Eissenstat, D.M. , Wells, C.E. , Yanai, R.D. , Whitbeck, J.L. 2000. Building roots in a changing environment: Implication for root longevity. New Phytology 147:3342.

ElSayed, A.I. , Rafudeen, M.S. , Golldack, D. 2014. Physiological aspects of raffinose family oligosaccharides in plants: Protection against abiotic stress. Plant Biology 16:18.

Espasandin, F. , Calzadilla, P. , Maiale, S. , Ruiz, O. , Sansberro, P. 2018. Overexpression of the arginine decarboxylase gene improves tolerance to salt stress in Lotus tenuis plants. Journal of Plant Growth Regulation 37(1):156165.

Essa, T.A. 2002. Effect of salinity stress on growth and nutrient composition of three soybeans (Glycine max L. Merrill) cultivars. Journal of Agronomy and Crop Science 188:8693.

FAO: Land and Water Division (NRL) . 2013. http://www.fao.org/ag/agl/agll/spush/intro.htm. Accessed 26 August 2013.

FAO . 1996. The Production Yearbook. Rome, Italy.

FAO . 2009. www.fao.org/askfao/topicsList.do?mainAreaId=20263.

Flemetakis, E. , Efrose, R.C. , Ott, T. , Stedel, C. , Aivalakis, G. , Udvardi, M.K. , Katinakis, P. 2006. Spatial and temporal organization of sucrose metabolism in Lotus japonicus nitrogen-fixing nodules suggests a role for the elusive alkaline/neutral invertase. Plant Molecular Biology 62:5369.

Flexas, J. , Bota, J. , Loreto, F. , Cornic, G. , Sharkey, T.D. 2004. Diffusive and metabolic limitations to photosynthesis under drought and salinity in C3 plants. Plant Biology (Stuttgart) 6(3):269279.

Flexas, J. , Ribas-Carb, M. , Bota, J. , Galms, J. , Henkle, M. , Martnez-Caellas, S. 2006. Decreased Rubisco activity during water stress is not induced by decreased relative water content but related to conditions of low stomatal conductance and chloroplast CO2 concentration. New Phytologist 172:7382.

Flowers, T.J. , Yeo, A.R. 1986. Ion relations of plant under drought and salinity. Australian Journal of Plant Physiology 13:7591.

Foyer, H.C. , Vanacker, H. , Gomez, L.D. , Harbinson, J. 2002. Regulation of photosynthesis and antioxidant metabolism in maize leaves at optimal and chilling temperatures: Review. Plant Physiology and Biochemistry 40:659668.

Fricke, W. , Akhiyarova, G. , Wei, W. , Alexandersson, E. , Miller, A. , Kjellbom, P.O. , Richardson, A. , et al. 2006. The short-term growth response to salt of the developing barley leaf. Journal of Experimental Botany 57:10791095.

Fuad-Hassan, A. , Tardieu, F. , Turc, O. 2008. Drought-induced changes in anthesis-silking interval are related to silk expansion: A spatio-temporal growth analysis in maize plants subjected to soil water deficit. Plant, Cell and Environment 31:13491360.

Garg, A.K. , Kim, J.K. , Owens, T.G. , Ranwala, A.P. , Choi, Y.D. , Kochian, L.V. , Wu, R.J. 2002. Trehalose accumulation in rice plants confers high tolerance levels to different abiotic stresses. Proceedings of the National Academy of Sciences 99:1589815903.

Grriz, A. , Dalmasso, M.C. , Marina, M. , Rivas, E.I. , Ruiz, O.A. , Pieckenstain, F.L. 2003. Polyamine metabolism during the germination of Sclerotinia sclerotiorum ascospores and its relation with host infection. New Phytologist 161:847854.

Gill, S.S. , Tuteja, N. 2010. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiology and Biochemistry 48:909930.

Gorham, J. , Wyn Jones, R.G. , Bristol, A. 1990. Partial characterization of t he trait for enhanced K+-Na+ discrimination in the D genome of wheat. Planta 180:590597.

Greenway, H. , Munns, R. 1980. Mechanisms of salt tolerance in nonhalophytes. Annual Review of Plant Physiology 31:149190.

Guo, W.X. , Mass, S.J. , Bronson, K.F. 2012. Relationship between cotton yield and soil electrical conductivity, topography, and Landsat imagery. Precision Agronomy 13:678692.

Guy, Ch. , Huber, J.L.A. , Huber, S.C. 1992. Sucrose phosphate synthase and sucrose accumulation at low temperature. Plant Physiology 100:502508.

Hahn, M. , Walbot, V. 1989. Effects of cold-treatment on protein synthesis and mRNA levels in rice leaves. Plant Physiology 91:930938.

Hashimoto, M. , Komatsu, S. 2007. Proteomic analysis of rice seedlings during cold stress. Proteomics Journal 7:12931302.

Henry, C. , Bledsoe, S.W. , Grifths, C.A. , Kollman, A. , Paul, M.J. , Sakr, S. , Lagrimini, M. 2015. Differential role for trehalose metabolism in salt-stressed maize. Plant Physiology 169:10721089.

Huner, N.P.A. ., quist, G ., Sarhan, F . 1998. Energy balance and acclimation to light and cold. Trends in Plant Science 3:224230.

Iba, K. 2002. Acclimative response to temperature stress in higher plants: Approaches of gene engineering for temperature tolerance. Annual Review Plant Biology 53:225245.

Intergovernmental Panel on Climate Change. 2007. http://www.ipcc.ch. Accessed 25 October 2007.

Ishitani, M. , Xiong, L. , Stevenson, B. , Zhu, J.K. 1997. Genetic analysis of osmotic and cold stress signal transduction in Arabidopsis: Interactions and convergence of abscisic acid-dependent and abscisic acid-independent pathways. The Plant Cell 9:19351949.

Janska, P. , Marsik, P. , Zelenkova S. , Ovesna, J. 2010. Cold stress and acclimation: What is important for metabolic adjustment?. Plant Biology 12:395405.

Ji, H. , Pardo, J.M. , Batelli, G. , Van Oosten, M.J. , Bressan, R.A. , Li, X. 2013. The salt overly sensitive (SOS) pathway: Established and emerging roles. Molecular Plant 6:275286.

18 Jiang, M. , Zhang, J. 2002. Water stress-induced abscisic acid accumulation triggers the increased generation of reactive oxygen species and up-regulates the activities of antioxidant enzymes in maize leaves. Journal of Experimental Botany 53:24012410.

Jones, H.G. 2007. Monitoring plant and soil water status: Established and novel methods revisited and their relevance to studies of drought tolerance. Journal of Experimental Botany 58:119130.

Kaiser, W.M. 1987. Effect of water deficit on photosynthetic capacity. Physiologia Plantarum 71:142149.

Kirkbride, J.H. 2006. The scientific name of narrow-leaf trefoil. Crop Science 46:21692170.

Kobayashi, F. , Maeta, E. , Terashima, A. , Kawaura, K. , Ogihara, Y. , Takumi, S. 2008. Development of abiotic stress tolerance via bZIP-type transcription factor LIP19 in common wheat. Journal of Experimental Botany 59:891905.

Luchli, A. 1984. Salt exclusion: An adaptation of legumes for crops and pastures under saline conditions. In Salinity Tolerance in Plants: Strategies for Crop Improvement. R.C. Staples, G.H. Toennissen (eds.). Wiley, New York, pp. 171187.

Lawlor, D.W. , Cornic, G. 2002. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. Plant, Cell and Environment 25:275294.

Len, P. , Sheen, J. 2003. Sugar and hormone connections. Trends in Plant Science 8:110116.

Li, Z. , Wakao, S. , Fischer, B. , Niyogi, K. 2009. Sensing and responding to excess light. Annual Review of Plant Biology 60:239260.

Lpez-Gmez, M. , Hidalgo-Castellanos, J. , Iribarne, C. , Lluch, C. 2014. Proline accumulation has prevalence over polyamines in nodules of Medicago sativa in symbiosis with Sinorhizobium meliloti during the initial response to salinity. Plant and Soil 374:149159.

Lu, Z.M. , Cheng, J.W. , Percy, R.G. , Zeiger, E. 1997. Photosynthetic rate, stomatal conductance and leaf area in two cotton species (Gossypium barbadense and Gossypium hirsutum) and their relation with heat resistance and yield. Australian Journal of Plant Physiology 24:693700.

Lunn, J.E. , Delorge, I. , Figueroa, C.M. , Van Dijck, P. , Stitt, M. 2014. Trehalose metabolism in plants. The Plant Journal 79:544567.

Lyons, J.M. 1973. Chilling injury in plants. Annual Review Plant Physiology 24:445466.

Marina, M. , Maiale, S. , Rossi, F. , Romero, M. , Rivas, M. , Grriz, A. , Ruiz, O. , Pieckenstain, F. 2008. Apoplastic polyamine oxidation plays different roles in local responses of tobacco to infection by the necrotrophic fungus Sclerotinia sclerotiorum and the biotrophic bacterium Pseudomonas. Plant Physiology 147:21642178.

Marraccini, P. , Vinecky, F. , Alves, G. , Ramos, H. , Elbet, S. , Vieira, N. , Carneiro, F. , et al. 2012. Differentially expressed genes and proteins upon drought acclimation in tolerant and sensitive genotypes of Coffea canephora. Journal of Experimental Botany 63:41914212.
Maruyama, K. , Urano, K. , Yoshiwara, K. , Morishita, Y. , Sakurai, N. , Suzuki, H. , Kojima, M. , et al. 2014. Integrated analysis of the effects of cold and dehydration on rice metabolites, phytohormones, and gene transcripts. Plant Physiology 164:17591771.
Mazzanti, A. , Darwich, N.A. , Cheppi, C. , Sarlangue, H. 1986. Persistencia de pasturas cultivadas en zonas ganaderas de la Pcia. de Buenos Aires. Revista Argentina de Produccin Animal 6:65.
McDonald, A.J.S. , Davies, W.J. 1996. Keeping in touch: Responses of the whole plant to deficits in water and nitrogen supply. Advances in Botanical Research 22:229300.
Meloni, D.A. , Oliva, M.A. , Ruiz, H.A. , Martinez, C.A. 2001. Contribution of proline and inorganic solutes to osmotic adjustment in cotton under salt stress. Journal of Plant Nutrition 24:599612.
Miller, G. , Suzuki, N. , Ciftci-Yilmaz, S. , Mittler, R. 2010. Reactive oxygen species homeostasis and signaling during drought and salinity stresses. Plant, Cell and Environment 33:453467.
Mittova, V. , Tal, M. , Volokita, M. , Guy, M. 2003. Up-regulation of the leaf mitochondrial and peroxisomal antioxidative systems in response to salt-induced oxidative stress in the wild salt-tolerant tomato species (Lycopersicon pennellii). Plant Cell and Environment 26:845856.
Munns, R. 1988. Effect of high external NaCl concentrations of ion transport within the shoot of Lupinus albus. I. Ions in xylem sap. Plant, Cell and Environment 11:283289.
Munns, R. 2002. Comparative physiology of salt and water stress. Plant, Cell and Environment 25:239250.
Munns, R. , James, R.A. , Luchli, A. 2006. Approaches to increasing the salt tolerance of wheat and other cereals. Journal of Experimental Botany 57:10251043.
Munns, R. , Schachtman, D.P. , Condon, A.G. 1995. The significance of a two-phase growth response to salinity in wheat and barley. Australian Journal of Plant Physiology 22:561569.
Nelson, N. , Yocum, C.F. 2006. Structure and function of photosystems I and II. Annual Review of Plant Biology 57:521565.
Nobel, P. 2009. Physicochemical and Environmental Plant Physiology. 4th edition. Elsevier, Los Angeles, CA
Noctor, G. , Veljovic-Jovanovic, S. , Driscoll, S. , Novitskaya, L. , Foyer, C.H. 2002. Drought and oxidative load in the leaves of C3 plants: A predominant role for photorespiration? Annals of Botany 89:841850.
Parvaiz, A. , Satyawati, S. 2008. Salt stress and phyto-biochemical responses of plants: A review. Plant Soil and Environment 54:8999.
Passioura, J. 2007. The drought environment: Physical, biological and agricultural perspectives. Journal of Experimental Botany 58:113117.
Passioura, J.B. 2010. Scaling up: The essence of effective agricultural research. Functional Plant Biology 37:585591.
Pastenes, C. , Pimentel, P. , Lillo, J. 2004. Leaf movements and photoinhibition in relation to water stress in field-grown beans. Journal of Experimental Botany 56:425433.
Paz, R.C. , Reinoso, H. , Espasandin, F.D. , Gonzalez Antivilo, F.A. , Sansberro, P.A. , Rocco, R.A. , Ruiz, O.A. , Menndez, A.B. 2014. Alkaline, saline and mixed salinealkaline stresses induce physiological and morph o-anatomical changes in Lotus tenuis shoots. Plant Biology 16:10421049.
Peoples, T.R. , Koch, D.W. , Smith, S.C. 1978. Relationship between chloroplast membrane fatty acid composition and photosynthetic response to a chilling temperature in four alfalfa cultivars. Plant Physiology 61:472473.
Perdomo, J.A. , Cap-Bau, S. , Carmo-Silva, E. , Galms, J. 2017. Rubisco and rubisco activase play an important role in the biochemical limitations of photosynthesis in rice, wheat, and maize under high temperature and water deficit. Frontiers in Plant Science 8:115.
Pinheiro, C. , Chaves, M.M. 2010. Photosynthesis and drought: can we make metabolic connections from available data? Journal of Experimental Botany 62:869882.
19 Quan, W. , Liu, X. , Wang, H. , Chan, Z. 2016. Comparative physiological and transcriptional analyses of two contrasting drought tolerant alfalfa varieties. Frontiers in Plant Science 6:12561272.
Rahman, M.d.A. ., Yong-Goo, K ., Iftekhar, A ., Liu, GSh ., Hyoshin, L ., Jeung Joo, L ., Byung-Hyun, L . 2016. Proteome analysis of alfalfa roots in response to water deficit stress. Journal of Integrative Agriculture 15:12751285.
Regier, N. , Streb, S. , Cocozza, C. , Schaub, M. , Cherubini, P. , Zeeman, S.C. , Frey, B. 2009. Drought tolerance of two black poplar (Populus nigra L.) clones: Contribution of carbohydrates and oxidative stress defense. Plant, Cell and Environment 32:17241736.
Rinalducci, S. , Egidi, M.G. , Karimzadeh, G. , Jazii, F.R. , Zolla, L. 2011. Proteomic analysis of a spring wheat cultivar in response to prolonged cold stress. Electrophoresis 32:18071818.
Rodziewicz, P. , Swarcewicz, B. , Chmielewska, K. , Wojakowska, A. , Stobiecki, M. 2014. Influence of abiotic stresses on plant proteome and metabolome changes. Acta Physiologiae Plantarum 36:119.
Sage, R.F. 2004. The evolution of C4 photosynthesis. New Phytology 161:341370.
Sage, R.F. , Way, D.A. , Kubien, D.S. 2008. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. Journal of Experimental Botany 59:15811595.
Saito, M. , Yoshida, M. 2011. Expression analysis of the gene family associated with raffinose accumulation in rice seedlings under cold stress. Journal of Plant Physiology 168:22682271.
Savitch, L.V. , Harney, T. , Huner, N.P.A. 2000. Sucrose metabolism in spring and winter wheat in response to high irradiance, cold stress and cold acclimation. Physiologia Plantarum 108:270278.
Seki, M. , Kamei, A. , Satou, M. , Sakurai, T. , Fujita, M. , Oono, Y. , Yamaguchi-Zhinozaki, K. , Zhinozaki, K . 2003. Transcriptome analysis in abiotic stress conditions in higher plants. Topics in Current Genetics 4:271295.
Setter, T.L. , Flannigan, B.A. 2001. Water deficit inhibits cell division and expression of transcripts involved in cell proliferation and endoreduplication in maize endosperm. Journal of Experimental Botany 52:14011408.
Sharp, R.E. 2002. Interaction with ethylene: Changing views on the role of abscisic acid in root and shoot growth responses to water stress. Plant, Cell and Environment 25:211222.
Shi, H. 2007. Integration of Ca2+ in plant drought and salt stress signal transduction pathways. In Advances in Molecular Breeding toward Drought and Salt tolerant Crops. M.A. Jenks , P.M. Hasegawa , S.M. Jain (eds.). Springer, Dordrecht, the Netherlands, pp. 141182.
Shinozaki, K. , Yamaguchi-Shinozaki, K. 2007. Gene networks involved in drought stress response and tolerance. Journal of Experimental Botany 58:221227.
Signorelli, S. , Corpas, F.J. , Borsani, O. , Barroso, J.B. , Monza, J. 2013. Water stress induces a differential and spatially distributed nitro-oxidative stress response in roots and leaves of Lotus japonicus. Plant Science 201202:137146.
Silveira, A.G. , Carvalho, F.E.L. 2016. Proteomics, photosynthesis and salt resistance in crops: An integrative view. Journal of Proteomics 143:2435.
Singleton, P.W. , Bohlool, B.B. 1983. The effect of salinity on the functional components of the soybean Rhizobium japonicum symbiosis. Crop Science 23:815818.
Song, L. , Jiang, L. , Chen, Y. , Shu, Y. , Bai, Y. , Guo, C. 2016a. Deep-sequencing transcriptome analysis of field-grown Medicago sativa L. crown buds acclimated to freezing stress. Functional and Integrative Genomics 16(5):495511.

Song, L. , Prince, S. , Valliyodan, B. , Joshi, T. , Maldonado dos Santos, J.V. , Wang, J. , Lin, L et al. 2016b. Genome-wide transcriptome analysis of soybean primary root under varying water deficit conditions. BMC Genomics 15:57.
Sun, C.X. , Gao, X.X. , Li, M.Q. , Fu, J.Q. , Zhang, Y.L. 2016. Plastic responses in the metabolome and functional traits of maize plants to temperature variations. Plant Biology 18:249261.
Suzuki, K. , Aoki, N. , Matsumura, H. , Okamura, M. , Ohsugi, R. , Shimono, H. 2015. Cooling water before panicle initiation increases chilling-induced male sterility and disables chilling-induced expression of genes encoding OsFKBP65 and heat shock proteins in rice spikelets. Plant, Cell and Environment 38:12551274.
Suzuki, N. , Mittler, R. 2006. Reactive oxygen species and temperature stresses: A delicate balance between signaling and destruction. Physiologia Plantarum 126:4551.
Taiz, L. , Zeiger, E. 2003. Plant Physiology. 3rd edition. Sinauer Associates Inc., Sunderland, MA.
Tang, X. , Mu, X. , Shao, H. , Wang, H. , Brestic, M. 2014. Global plant-responding mechanisms to salt stress: Physiological and molecular levels and implications in biotechnology. Critical Reviews in Biotechnology. Early Online: 113.
Tardieu, F. , Simonneau, T. 1998. Variability among species of stomatal control under fluctuating soil water status and evaporative demand: Modelling isohydric and anisohydric behaviors. Journal of Experimental Botany 49:419432.
Tarkowski, .P. , Van den Ende, W. 2015. Cold tolerance triggered by soluble sugars: A multifaceted countermeasure. Frontiers in Plant Science 6:17.
Taylor, S.H. , Ripley, B.S. , Woodward, F.I. , Osborne, C.P. 2011. Drought limitation of photosynthesis differs between C3 and C4 grass species in a comparative experiment. Plant, Cell and Environment 34:6575.
Tezara, W ., Mitchell, V.J. ., Driscoll, S.D. ., Lawlor, D.W. . 1999. Water stress inhibits plant photosynthesis by decreasing coupling factor and ATP. Nature 401:914917.
Tian, X. , Liu, Y. , Huang, Z. , Duan, H. , Tong, J. , He, X. , Gu, W. , Ma, H. , Xiao, L. 2015. Comparative proteomic analysis of seedling leaves of cold-tolerant and -sensitive spring soybean cultivars. Molecular Biology Reports 42:581601.
Turner, N.C. ., Jones, M.M. . 1980. Turgor maintenance by osmotic adjustment: A review and evaluation. In Adaptation of plants to water and high temperature stress. N.C. Turner, P.J. Kramer (eds.). Wiley InterScience, New York, pp. 87103.
Tuteja, N. , Gill, S. , Tuteja, R. 2011. Plant responses to abiotic stresses: Shedding light on salt, drought, cold, and heavy metal stress. In Omics and Plant Stress Tolerance. N. Tuteja , S. Gill , R. Tuteja (eds.). Bentham Science Publisher, Sharjah, UAE, pp. 39 39.
UNESCO Water Portal . 2007. http://www.unesco.org/water. Accessed 25.
Upchurch, R.G. 2008. Fatty acid unsaturation, mobilization, and regulation in the response of plants to stress. Biotechnology Letters 30:967977.
USSL STAFF . 1954. Diagnosis and improvement of saline and alkali soils. In Agriculture Handbook 60. L.A. Richards (ed.). USDA, Washington, DC (Reprinted 1969).
20 Vargas, W.A. , Pontis, H.G. , Salerno, G.L. 2007. Differential expression of alkaline and neutral invertases in response to environmental stresses: Characterization of an alkaline isoform as a stress-response enzyme in wheat leaves. Planta 226:15351545.
Wang, X. , Shan, X. , Wu, Y. , Su, S. , Li, S. , Liu, H. , Han, J. , Xue, C. , Yuan, Y. 2016. iTRAQ-based quantitative proteomic analysis reveals new metabolic pathways responding to chilling stress in maize seedlings. Journal of Proteomics 146:1424.
Westgate, M.E. , Boyer, J.S. 1985. Carbohydrate reserves and reproductive development at low leaf water potentials in maize. Crop Science 25:762769.
Wilkinson, S. , Davies, J. 2002. ABA-based chemical signaling: The coordination of responses to stress in plants. Plant, Cell and Environment 25:195210.
Willemot, C. , Hope, H.J. , Williams, R.J. , Michaud, R. 1977. Changes in fatty acid composition of winter wheat during frost hardening. Cryobiology 14:8793.
Wingler, A. , Lea, P.J. , Quick, W.P. , Leegood, R.C. 2000. Photorespiration: Metabolic pathways and their role in stress protection. Philosophical Transactions of the Royal Society of London B: Biological Sciences 355:15171529.
Wu, G. , Zhou, Z. , Chen, P. , Tang, X. , Shao, H. , Wang, H. 2014. Comparative ecophysiological study of salt stress for wild and cultivated soybean species from the Yellow River Delta, China. The Scientic World Journal. Article ID 651745.
Xiong, L. 2007. Abscisic acid i n plant response and adaptation to drought and salt stress. In Advances in Molecular Breeding toward Drought and Salt Tolerant Crops. M. Jenks , P. Hasegawa , S. Jain (eds.). Springer, Dordrecht, the Netherlands, pp. 193221.
Xiong, L. , Ishitani, M. 2006. Stress signal transduction: Components, pathways and network integration. In Abiotic Stress Tolerance in Plants. A.K. Rai , T. Takabe (eds.). Springer, Dordrecht, the Netherlands, pp. 329.
Xiong, L. , Schumaker, K.S. , Zhu, J.K. 2002. Cell signaling during cold, drought, and salt stress. The Plant Cell 14:S165S183.
Xiong, L. , Zhu, J.K. 2002. Molecular and genetic aspects of plant responses to osmotic stress. Plant, Cell and Environment 25:131139.
Xu, J. , Li, Y. , Sun, J. , Du, L. , Zhang, Y. , Yu, Q. , Liu, X. 2013. Comparative physiological and proteomic response to abrupt low temperature stress between two winter wheat cultivars differing in low temperature tolerance. Plant Biology 15:292303.
Yadav, S. , Irfan, M. , Ahmad, A. , Hayat, S. 2011. Causes of salinity and plant manifestations to salt stress: A review. Journal of Environmental Biology 32:667685.
Yan, J. , Wang, B. , Jiang, Y. , Cheng, L. , Wu, T. 2013. GmFNSII-controlled soybean flavone metabolism responds to abiotic stresses and regulates plant salt tolerance. Plant and Cell Physiology 55:7486.
Yan, W. , Zhong, Y. , Shangguan, Z. 2017. Rapid response of the carbon balance strategy in Robinia pseudoacacia and Amorpha fruticosa to recurrent drought. Environmental and Experimental Botany 138:4656.
Yeo, A.R. , Lee, K.S. , Izard, P. , Boursier, P.J. , Flowers, T.J. 1991. Short- and long-term effects of salinity on leaf growth in rice (Oryza sativa L.). Journal of Experimental Botany 42:881889.
Yin, Y. , Yang, R. , Han, Y. , Gu, Z. 2015. Comparative proteomic and physiological analyses reveal the protective effect of exogenous calcium on the germinating soybean response to salt stress. Journal of Proteomics 113:110126.
Yokoi, S. , Quintero, F.J. , Cubero, B. , Ruiz, M.T. , Bressan, R.A. , Hasegawa, P.M. , Pardo, J.M. 2002. Differential expression and function of Arabidopsis thaliana NHX Na+/H+ antiporters in the salt stress response. Plant Journal 30:529539.
Zhang, H. , Han, B. , Wang, T. , Chen, S. , Li, H. , Zhang, Y. , Dai, S. 2012. Mechanisms of plant salt response: Insights from proteomics. Journal of Proteome Research 11:4967.
Zhang, L. , Ma, H. , Chen, T. , Pen, J. , Yu, S. , Zhao, X. 2014. Morphological and physiological responses of cotton (Gossypium hirsutum L.) plant to salinity. PLoS One 9:e112807.
Zheng, Q. , Liu, J. , Liu, R. , Wu, H. , Jiang, C. , Wang, C. , Guan, Y. 2016. Temporal and spatial distributions of sodium and polyamines regulated by brassinosteroids in enhancing tomato salt resistance. Plant Soil 400:147164.
Zhou, F. , Sosa, J. , Feldmann, K.A. 2007. High throughput approaches for the identification of salt tolerance genes in plants. In Advances in Molecular Breeding toward Drought and Salt Tolerant Crops. M.A. Jenks , P.M. Hasegawa, S.M Jain. (eds.), Springer, Dordrecht, the Netherlands, pp. 359 359.
Zhu, J.K. 2003. Regulation of ion homeostasis under salt stress. Current Opinion in Plant Biology 6:441445.

Zhu, S. Q. , Yu, C. M. , Liu, X. Y. , Ji, B. H. , Jiao, D. M. 2007. Changes in unsaturated levels of fatty acids in thylakoid PSII membrane lipids during chilling-induced resistance in rice. Journal of Integrative Plant Biology 49:463471.

Zhuo, Ch. , Wang, T. , Lu, S. , Zhao, Y. , Li, X. , Guo, Z. 2013. A cold responsive galactinol synthase gene from Medicago falcata (MfGolS1) is induced by myo-inositol and confers multiple tolerances to abiotic stresses. Physiologia Plantarum 149:6778.

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Ainsworth, E.A. , Ort, D.R. (2010) How do we improve crop production in a warming world? Plant Physiology 154, 526530.

Cernusak, L.A. , Tcherkez, G. , Keitel, C. , Cornwell, W.K. , Santiago, L.S. , Knohl, A. , Barbour, M.M. , et al. (2009) Why are non-photosynthetic tissues generally 13C enriched compared with leaves in C3 plants? Review and synthesis of current hypotheses. Functional Plant Biology 36, 199213.

Clark, A.M. , Jacobsen, K.R. , Bostwick, D.E. , Dannenhoffer, J.M. , Skaggs, M.I. , Thompson, G.A. (1997) Molecular characterization of a phloem-specific gene encoding the filament protein, phloem protein 1 (PP1), from Cucurbita maxima. Plant Journal 12, 4961.

Devaux, M. , Ghashghaie, J. , Bert, D. , Lambrot, C. , Gessler, A. , Bathellier, C. , Ogee, J. , Loustau, D. (2009) Carbon stable isotope ratio of phloem sugars in mature pine trees throughout the growing season: Comparison of two extraction methods. Rapid Communications in Mass Spectrometry 23, 25112518.

Dinant, S. (2008) Phloem, transport between organs and long-distance signalling. Comptes Rendus Biologies 331, 334346.

Dinant, S. , Bonnemain, J.L. , Girousse, C. , Kehr, J. (2010) Phloem sap intricacy and interplay with aphid feeding. Comptes Rendus Biologies 333, 504515.

Farquhar, G.D. , Ehleringer, J.R. , Hubick, K.T. (1989) Carbon isotope discrimination and photosynthesis. Annual Review of Plant Physiology and Plant Molecular Biology 40, 503537.

Farquhar, G.D. , OLeary, M.H. , Berry, J.A. (1982) On the relationship between carbon isotope discrimination and the intercellular carbon dioxide concentration in leaves. Australian Journal of Plant Physiology 9, 121137.

Farquhar, G.D. , Richards, R.A. (1984) Isotopic composition of plant carbon correlates with water use efficiency of wheat genotypes. Australian Journal of Plant Physiology 11, 539552.

Gessler, A. , Brandes, E. , Buchmann, N. , Helle, G. , Rennenberg, H. , Barnard, R.L. (2009) Tracing carbon and oxygen isotope signals from newly assimilated sugars in the leaves to the tree-ring archive. Plant Cell and Environment 32, 780795.

Gessler, A. , Rennenberg, H. , Keitel, C. (2004) Stable isotope composition of organic compounds transported in the phloem of European beechEvaluation of different methods of phloem sap collection and assessment of gradients in carbon isotope composition during leaf-to-stem transport. Plant Biology 6, 721729.

Gessler, A. , Tcherkez, G. , Peuke, A.D. , Ghashghaie, J. , Farquhar, G.D. (2008) Experimental evidence for diel variations of the carbon isotope composition in leaf, stem and phloem sap organic matter in Ricinus communis. Plant Cell and Environment 31, 941953.

Keitel, C. , Matzarakis, A. , Rennenberg, H. , Gessler, A. (2006) Carbon isotopic composition and oxygen isotopic enrichment in phloem and total leaf organic matter of European beech (Fagus sylvatica L.) along a climate gradient. Plant Cell and Environment 29, 14921507.

Kennedy, J.S. , Mittler, T.E. (1953) A method of obtaining phloem sap via the mouth-parts of aphids. Nature 171, 528528.

Knop, C. , Stadler, R. , Sauer, N. , Lohaus, G. (2004) AmSUT1, a sucrose transporter in collection and transport phloem of the putative symplastic phloem loader Alonsoa meridionalis. Plant Physiology 134, 204214.

Lahuta, L.B. (2006) Biosynthesis of raffinose family oligosaccharides and galactosyl pinitols in developing and maturing seeds of winter vetch (Vicia villosa Roth.). Acta Societatis Botanicorum Poloniae 75, 219227.

Lalonde, S. , Tegeder, M. , Throne-Holst, M. , Frommer, W.B. , Patrick, J.W. (2003) Phloem loading and unloading of sugars and amino acids. Plant Cell and Environment 26, 3756.

Ma, J.M. , Horbowicz, M. , Obendorf, R.L. (2005) Cyclitol galactosides in embryos of buckwheat stem-leaf-seed explants fed D-chiro-inositol, myo-inositol or D-pinitol. Seed Science Research 15, 329338.

Merchant, A. (2012) Developing phloem 13C and sugar composition as indicators of water deficit in Lupinus angustifolius. Hortscience 47, 691696.

Merchant, A. , Peuke, A.D. , Keitel, C. , Macfarlane, C. , Warren, C. , Adams, M.A. (2010a) Phloem sap and leaf 13C, carbohydrates and amino acid concentrations in Eucalyptus globulus change systematically according to flooding and water deficit treatment. Journal of Experimental Botany 61, 17851793.

Merchant, A. , Tausz, M. , Keitel, C. , Adams, M.A. (2010b) Relations of sugar composition and 13C in phloem sap to growth and physiological performance of Eucalyptus globulus (Labill) Plant Cell and Environment 33, 13611368.

Merchant, A. , Wild, B. , Richter, A. , Bellot, S. , Adams, M.A. , Dreyer, E. (2011) Compound-specific differences in (13)C of soluble carbohydrates in leaves and phloem of 6-month-old Eucalyptus globulus (Labill). Plant Cell and Environment 34, 15991608.

Munch, E. (1930) Die Stoffbewegungen in der Pflanze. Jena, Germany: Gustav Fischer Verlagsb.

Noiraud, N. , Maurousset, L. , Lemoine, R. (2001) Identification of a mannitol transporter, AgMaT1, in celery phloem. Plant Cell 13, 695705.

Oparka, K.J. , Turgeon, R. (1999) Sieve elements and companion cellsTraffic control centers of the phloem. Plant Cell 11, 739750.

Pate, J.S. , Atkins, C.A. (1983) Xylem and phloem transport and the functional economy of carbon and nitrogen of a legume leaf. Plant Physiology 71, 835840.

Pate, J.S. , Sharkey, P.J. , Lewis, O.A.M. (1974) Phloem bleeding form legume fruitsTechnique for study of fruit nutrition. Planta 120, 229243.

Pate, J. , Shedley, E. , Arthur, D. , Adams, M. (1998) Spatial and temporal variations in phloem sap composition of plantation-grown Eucalyptus globulus. Oecologia 117, 312322.

25 Peterbauer, T. , Brereton, I. , Richter, A. (2003) Identification of a digalactosyl ononitol from seeds of adzuki bean (Vigna angularis). Carbohydrate Research 338, 20172019.

Pommerenig, B. , Papini-Terzi, F.S. , Sauer, N. (2007) Differential regulation of sorbitol and sucrose loading into the phloem of Plantago major in response to salt stress. Plant Physiology 144, 10291038.

Pritchard, J. (2007) Solute transport in the phloem. In: Plant Solute Transport, A.R. Yeo , T.J. Flowers (Eds.). Oxford: Blackwell Publishing.

Ramsperger-Gleixner, M. , Geiger, D. , Hedrich, R. , Sauer, N. (2004) Differential expression of sucrose transporter and polyol transporter genes during maturation of common plantain companion cells. Plant Physiology 134, 147160.

Raven, J.A. (1991) Long-term functioning of enucleate sieve elementsPossible mechanisms of damage avoidance and damage repair. Plant Cell and Environment 14, 139146.

Seibt, U. , Rajabi, A. , Griffiths, H. , Berry, J.A. (2008) Carbon isotopes and water use efficiency: Sense and sensitivity. Oecologia 155, 441454.

Smith, J.A.C. , Milburn, J.A. (1980) Osmoregulation and the control of phloem-sap composition in Ricinus-communis L. Planta 148, 2834.
Sowinski, P. (1999) Transport of photoassimilates in plants under unfavourable environmental conditions. Acta Physiologiae Plantarum 21, 7585.
Stitt, M. , Lunn, J. , Usadel, B. (2010) Arabidopsis and primary photosynthetic metabolismMore than the icing on the cake. Plant Journal 61, 10671091.
Taiz, L. , Zeiger, E. (2010) Plant Physiology, 5th edition. Sunderland: Sinauer Associates Inc.
Thompson, M.V. (2006) Phloem: The long and the short of it. Trends in Plant Science 11, 2632.
Turgeon, R. (1991) Symplastic phloem loading and the sink-source transition in leaves: A model. In: Recent Advances in Phloem Transport and Assimilate Compartmentation, J.L. Bonnemain , S. Delrot , W.J. Lucas , J. Dainty (Eds.). Nantes, France: Quest Editions, pp. 1822.
Turgeon, R. (2000) Plasmodesmata and solute exchange in the phloem. Australian Journal of Plant Physiology 27, 521529.
Turgeon, R. (2006) Phloem loading: How leaves gain their independence. Bioscience 56, 1524.
Turgeon, R. (2010) The role of phloem loading reconsidered. Plant Physiology 152 , 18171823.
Turgeon, R. , Medville, R. , Nixon, K.C. (2001) The evolution of minor vein phloem and phloem loading. American Journal of Botany 88, 13311339.
Turgeon, R. , Wolf, S. (2009) Phloem transport: Cellular pathways and molecular trafficking. Annual Review of Plant Biology 60, 207221.
van Bel, A.J.E. (2003) The phloem, a miracle of ingenuity. Plant Cell and Environment 26, 125149.
van Bel, A.J.E. , Hendriks, J.H.M. , Boon, E.J.M.C. , Gamalei, Y.V. , vandeMerwe, A.P. (1996) Different ratios of sucrose/raffinose-induced membrane depolarizations in the mesophyll of species with symplasmic (Catharanthus roseus, Ocimum basilicum) or apoplasmic (Impatiens walleriana, Vicia faba) minor-vein configurations. Planta 199, 185192.
van Bel, A.J.E. , Hess, P.H. (2008) Hexoses as phloem transport sugars: The end of a dogma? Journal of Experimental Botany 59, 261272.

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Agarwal M , Hao Y , Kapoor A , Dong CH , Fujii H , Zheng X , Zhu JK (2006) A R2R3 type MYB transcription factor is involved in the cold regulation of CBF genes and in acquired freezing tolerance. Journal of Biological Chemistry 281:3763637645.
Agrawal GK , Agrawal SK , Shibato J , Iwahashi H , Rakwal R (2003) Novel rice MAP kinases OsMSRMK3 and OsWJUMK1 involved in encountering diverse environmental stresses and developmental regulation. Biochemical and Biophysical Research Communications 300:775783.
Agrawal GK , Rakwa R , Iwahashi H (2002) Isolation of novel rice (Oryza sativa L.) multiple stress responsive MAP kinase gene, OsMSRMK2, whose mRNA accumulates rapidly in response to environmental cues. Biochemical and Biophysical Research Communications 294:10091016.
Alexandre J , Lassalles J , Kado R (1990) Opening of Ca2+ channels in isolated red beet root vacuole membrane by inositol 1,4,5-trisphosphate. Nature 343:567570.
Allen GJ , Muir SR , Sanders D (1995) Release of Ca2+ from individual plant vacuoles by both InsP3 and cyclic ADP-ribose. Science 268:735737.
Anderson JA , Huprikar SS , Kochian LV , Lucas WJ , Gaber RF (1992) Functional expression of a probable A. thaliana potassium channel in S. cerevisiae. Proceedings of the National Academy of Sciences of the United States of America 89:37363740.
Apse MP , Sottosanto JB , Blumwald E (2003) Vacuolar cation/H+ exchange, ion homeostasis, and leaf development are altered in a T-DNA insertional mutant of AtNHX1, the Arabidopsis vacuolar Na+/H+ antiporter. Plant Journal 36:229239.
Asano T , Hakata M , Nakamura H , Aoki N , Komatsu S , Ichikawa H , Hirochika H , Ohsugi R (2011) Functional characterisation of OsCPK21, a calcium-dependent protein kinase that confers salt tolerance in rice. Plant Molecular Biology 75:179191.
Asano T , Hayashi N , Kobayashi M , Aoki N , Miyao A , Mitsuhara I , Ichikawa H , et al. (2012) A rice calcium-dependent protein kinase OsCPK12 oppositely modulates salt-stress tolerance and blast disease resistance. Plant Journal 69:2636.
Atienza JM , Jiang X , Garciadeblas B , Mendoza I , Zhu JK , Pardo JM , Quintero FJ (2007) Conservation of the salt overly sensitive pathway in rice. Plant Physiology 143:10011012.
Baisakh N , Rao MVR , Rajasekaran K , Subudhi P , Janda J , Galbraith D , Vanier C , Pereira A (2012) Enhanced salt stress tolerance of rice plants expressing a vacuolar H+-ATPase subunit c1 (SaVHAc1) gene from the halophyte grass Spartina alterniflora Lisel. Plant Biotechnology Journal 10:453464.
Banti V , Mafessoni F , Loreti E , Alpi A , Perata P (2010) The heat-inducible transcription factor HsfA2 enhances anoxia tolerance in Arabidopsis. Plant Physiology 152:14711483.
Barragn V , Leidi EO , Andrs Z , Rubio L , De Luca A , Fernndez JA , Cubero B , Pardo JM (2012) Ion exchangers NHX1 and NHX2 mediate active potassium uptake into vacuoles to regulate cell turgor and stomatal function in Arabidopsis. Plant Cell 24:11271142.
Bassil E , Coku A , Blumwald E (2012) Cellular ion homeostasis: Emerging roles of intracellular NHX Na+/H+ antiporters in plant growth and development. Journal of Experimental Botany 63:57275740. doi:10.1093/jxb/ers250
Bassil E , Ohto MA , Esumi T , Tajima H , Zhu Z , Cagnac O , Belmonte M , Peleg Z , Yamaguchi T , Blumwald E (2011a) The Arabidopsis intracellular Na+/H+ antiporters NHX5 and NHX6 are endosome associated and necessary for plant growth and development. Plant Cell 23:224239.
Bassil E , Tajima H , Liang YC , Ohto MA , Ushijima K , Nakano R , Esumi T , Coku A , Belmonte M , Blumwald E (2011b) The Arabidopsis Na+/H+ antiporters NHX1 and NHX2 control vacuolar pH and K+ homeostasis to regulate growth, flower development, and reproduction. Plant Cell 23:34823497.
40 Borsani O , Cuartero J , Fernndez JA , Valpuesta V , Botella MA (2001) Identification of two loci in tomato reveals distinct mechanisms for salt tolerance. Plant Cell 13:873887.
Chae MJ , Lee JS , Nam MH , Cho K , Hong JY , Yi SA , Suh SC , Yoon IS (2007) A rice dehydration-inducible SNF1-related protein kinase 2 phosphorylates an abscisic acid responsive element-binding factor and associates with ABA signaling. Plant Molecular Biology 63:151169.
Chinnusamy V , Jagendorf A , Zhu JK (2005) Understanding and improving salt tolerance in plants. Crop Science 45:437448.
Chung PJ , Kim YS , Jeong JS , Park SH , Nahm BH , Kim JK (2009) The histone deacetylase OsHDAC1 epigenetically regulates the OsNAC6 gene that controls seedling root growth in rice. Plant Journal 59:764776.
Dai X , Xu Y , Ma Q , Xu W , Wang T , Xue Y , Chong K (2007) Overexpression of an R1R2R3 MYB gene, OsMYB3R-2, increases tolerance to freezing, drought, and salt stress in transgenic Arabidopsis. Plant Physiology 143:17391751.
Diedhiou CJ , Popova OV , Dietz KJ , Golldack D (2008) The SNF1-type serine-threonine protein kinase SAPK4 regulates stress-responsive gene expression in rice. BMC Plant Biology 8:49.

Ding L , Zhu JK (1997) Reduced sodium uptake in the salt-hypersensitive sos1 mutant of Arabidopsis thaliana. Plant Physiology 113:795799.

Ding Z , Li S , An X , Liu X , Qin H , Wang D (2009) Transgenic expression of MYB15 confers enhanced sensitivity to abscisic acid and improved drought tolerance in Arabidopsis thaliana. Journal of Genetics and Genomics 36:1729.

Duan J , Cai W (2012) OsLEA3-2, an abiotic stress induced gene of rice plays a key role in salt and drought tolerance. PLOS One 7(9):e45117. doi:10.1371/journal.pone.0045117

Dubos C , Stracke R , Grotewold E , Weisshaar B , Martin C , Lepiniec L (2010) MYB transcription factors in Arabidopsis. Trends in Plant Science 15:573581.

Dubouzet JG , Sakuma Y , Ito Y , Kasuga M , Dubouzet EG , Miura S , Seki M , Shinozaki K , Yamaguchi-Shinozaki K (2003) OsDREB genes in rice, Oryza sativa L., encode transcription activators that function in drought-, high-salt- and cold-responsive gene expression. Plant Journal 33:751763.

Fu SF , Chou WC , Huang DD , Huang HJ (2002) Transcriptional regulation of a rice mitogen-activated protein kinase gene, OsMAPK4, in response to environmental stresses. Plant and Cell Physiology 43:958963.

Fujita Y , Fujita M , Shinozaki K , Yamaguchi-Shinozaki K (2011) ABA-mediated transcriptional regulation in response to osmotic stress in plants. Journal of Plant Research 124(4):509525. doi: 10.1007/s10265-011-0412-3.

Fukuda A , Nakamura A , Hara N , Toki S , Tanaka Y (2011) Molecular and functional analyses of rice NHX-type Na+/H+ antiporter genes. Planta 233:175188.

Fukuda A , Nakamura A , Tagiri A , Tanaka H , Miyao A , Hirochika H , Tanaka Y (2004) Function, intracellular localization and the importance in salt tolerance of a vacuolar Na(+)/H(+) antiporter from rice. Plant and Cell Physiology 45:146159.

Furihata T , Maruyama K , Fujita Y , Umezawa T , Yoshida R , Shinozaki K , Yamaguchi-Shinozaki K (2006) Abscisic acid dependent multisite phosphorylation regulates the activity of a transcription activator AREB1. Proceedings of the National Academy of Sciences of the United States of America 103:19881993.

Galon Y , Finkler A , Fromm H (2010) Calcium-regulated transcription in plants. Molecular Plant 3:653669.

Gao P , Bai X , Yang L , Lv D , Li Y , Cai H , Ji W , Guo D , Zhu Y (2010) Over-expression of osa-MIR396c decreases salt and alkali stress tolerance. Planta 231:9911001.

Gao P , Bai X , Yang L , Lv D , Pan X , Li Y , Cai H , Ji W , Chen Q , Zhu Y (2011) osa-MIR393: A salinity- and alkaline stress-related microRNA gene. Molecular Biology Reports 38:237242.

Garciadebls B , Senn ME , Bauelos MA , Rodrguez-Navarro A (2003) Sodium transport and HKT transporters: The rice model. Plant Journal 34:788801.

Garg AK , Kim JK , Owens TG , Ranwala AP , Choi YD , Kochian LV , Wu RJ (2002) Trehalose accumulation in rice plants confers high tolerance levels to different abiotic stresses. Proceedings of the National Academy of Sciences of the United States of America 99:1589815903.

Gilroy S , Read ND , Trewavas AJ (1990) Elevation of cytoplasmic calcium by caged calcium or caged inositol triphosphate initiates stomatal closure. Nature 346:769771.

Golldack D , Quigley F , Michalowski CB , Kamasani UR , Bohnert HJ (2003) Salinity stress-tolerant and -sensitive rice (Oryza sativa L.) regulate AKT1-type potassium channel transcripts differently. Plant Molecular Biology 51:7181.

Guo J , Duff HJ (2006) Calmodulin kinase II accelerates L-type Ca2+ current recovery from inactivation and compensates for the direct inhibitory effect of [Ca2+]i in rat ventricular myocytes. The Journal of Physiology 574(2):509518.

Halfter U , Ishitani M , Zhu JK (2000) The Arabidopsis SOS2 protein kinase physically interacts with and is activated by the calcium-binding protein SOS3. Proceedings of the National Academy of Sciences of the United States of America 97:37353740.

Hoshida H , Tanaka Y , Hibino T , Hayashi Y , Tanaka A , Takabe T , Takabe T (2000) Enhanced tolerance to salt stress in transgenic rice that overexpresses chloroplast glutamine synthetase. Plant Molecular Biology 43:103111.

Hossain MA , Cho JI , Han M , Ahn CH , Jeon JS , An G , Park PB (2010) The ABRE binding bZIP transcription factor OsABF2 is a positive regulator of abiotic stress and ABA signaling in rice. Journal of Plant Physiology 167:15121520.

Hou X , Xie K , Yao J , Qi Z , Xiong L (2009) A homolog of human ski-interacting protein in rice positively regulates cell viability and stress tolerance. Proceedings of the National Academy of Sciences of the United States of America 106:64106415.

Hu H , Dai M , Yao J , Xiao B , Li X , Zhang Q , Xiong L (2006) Overexpressing a NAM, ATAF, and CUC (NAC) transcription factor enhances drought resistance and salt tolerance in rice. Proceedings of the National Academy of Sciences of the United States of America 103:1298712992.

Hu H , You J , Fang Y , Zhu X , Qi Z , Xiong L (2008) Characterization of transcription factor gene SNAC2 conferring cold and salt tolerance in rice. Plant Molecular Biology 67:169181.

Huang XY , Chao DY , Gao JP , Zhu MZ , Shi M , Lin HX (2009) A previously unknown zinc finger protein, DST, regulates drought and salt tolerance in rice via stomatal aperture control. Genes & Development 23:18051817.

Ito Y , Katsura K , Maruyama K , Taji T , Kobayashi M , Seki M , Shinozaki K , Shinozaki KY (2006) Functional analysis of rice DREB1/CBF-type transcription factors involved in cold responsive gene expression in transgenic rice. Plant and Cell Physiology 47:141153.

41 Jan A , Maruyama K , Todaka D , Kidokoro S , Abo M , Yoshimura E , Shinozaki K , Nakashima K , Shinozaki KY (2013) OsTZF1, a CCCH-tandem zinc finger protein, confers delayed senescence and stress tolerance in rice by regulating stress-related genes. Plant Physiology 161:12021216. doi:10.1104/pp.112.205385.

Jang IC , Oh SJ , Seo JS , Choi WB , Song SI , Kim CH , Kim YS , et al. (2003) Expression of a bifunctional fusion of the Escherichia coli genes for trehalose-6-phosphate synthase and trehalose-6-phosphate phosphatase in transgenic rice plants increases trehalose accumulation and abiotic stress tolerance without stunting growth. Plant Physiology 131:516524.

Jeong MJ , Lee SK , Kim BG , Kwon TR , Cho WS , Park YT , Lee JO , Kwon HB , Byun MO , Park SC (2006) A rice (Oryza sativa L.) MAP kinase gene, OsMAPK44, is involved in response to abiotic stresses. Plant Cell, Tissue and Organ Culture 85:151160.

Jin H , Martin C (1999) Multifunctionality and diversity within the plant MYB-gene family. Plant Molecular Biology 41:577585.

Jonak C , Okresz L , Bogre L , Hirt H (2002) Complexity, cross talk and integration of plant MAP kinase signaling. Current Opinion in Plant Biology 5:415424.

Jossier M , Bouly JP , Meimoun P , Arjmand A , Lessard P , Hawley S , Grahame Hardie D , Thomas M (2009) SnRK1 (SNF1-related kinase 1) has a central role in sugar and ABA signalling in Arabidopsis thaliana. Plant Journal 59:316328.

Jung C , Seo JS , Han SW , Koo YJ , Kim CH , Song SI , Nahm BH , Choi YD , Cheong JJ (2008) Over-expression of AtMYB44 enhances stomatal closure to confer abiotic stress tolerance in transgenic Arabidopsis. Plant Physiology 146:623635.

Kim JA , Agrawal GK , Rakwal R , Han KS , Kim KN , Yun CH , Heu S , Park SY , Lee YH , Jwa NS (2003) Molecular cloning and mRNA expression analysis of a novel rice (Oryza sativa L.) MAPK kinase kinase, OsEDR1, an ortholog of Arabidopsis AtEDR1, reveal its role in defense/stress signalling pathways and development. Biochemical and Biophysical Research Communications 300(4):868876.

Kobayashi Y , Murata M , Minami H , Yamamoto S , Kagaya Y , Hobo T , Yamamoto A , Hattori T (2005) Abscisic acid-activated SNRK2 protein kinases function in the gene-regulation pathway of ABA signal transduction by phosphorylating ABA response element binding factors. Plant Journal 44:939949.

Kobayashi Y , Yamamoto S , Minami H , Kagaya Y , Hattori T (2004) Differential activation of the rice sucrose nonfermenting1-related protein kinase2 family by hyperosmotic stress and abscisic acid. Plant Cell 16:11631177.

Koh S , Lee SC , Kim MK , Koh JH , Lee S , An G , Choe S , Kim SR (2007) T-DNA tagged knockout mutation of rice OsGSK1, an orthologue of Arabidopsis BIN2, with enhanced tolerance to various abiotic stresses. Plant Molecular Biology 65:453:466.

Kulik A , Wawer I , Krzywinska E , Bucholc M , Dobrowolska G (2011) SnRK2 protein kinaseskey regulators of plant response to abiotic stresses. OMICS: A Journal of Integrative Biology 15:859872.

Kumar K , Kumar M , Kim SR , Ryu H , Cho YG (2013) Insights into genomics of salt stress response in rice. Rice 6:27. doi:10.1186/1939-8433-6-27.

Kumar M (2013) Crop plants and abiotic stresses. Journal of Biomolecular Research and Therapeutics 3:e125. doi: 10.4172/2167-7956.1000e125.

Kumar M , Choi J , An G , Kim S-R (2017) Ectopic expression of OsSta2 enhances salt stress tolerance in rice. Frontiers in Plant Science 8:316. doi:10.3389/fpls.2017.00316.

Kumar M , Gho YS , Jung KH , Kim SR (2017) Genome-wide identification and analysis of genes, conserved between japonica and indica rice cultivars, that respond to low-temperaturestress at the vegetative growth stage. Frontiers in Plant Science 30;8:1120. https://doi.org/10.3389/fpls.2017.01120.

Kumar M , Lee SC , Kim JY , Kim SJ , Aye SS , Kim SR (2014). Over-expression of dehydrin gene, OsDhn1, improves drought and salt stress tolerance through scavenging of reactive oxygen species in rice (Oryza sativa L.). Journal of Plant Biology 57:383393. doi:10.1007/s12374-014-0487-1.

Lee SK , Kim BG , Kwon TR , Jeong MJ , Park SR , Lee JW , Byun MO , et al. (2011) Overexpression of the mitogen-activated protein kinase gene OsMAPK33 enhances sensitivity to salt stress in rice (Oryza sativa L.). Journal of Biosciences 36:139151.

Lin LL , Wartmann M , Lin AY , Knopf JL , Seth A , Davis RJ (1993) cPLA2 is phosphorylated and activated by MAP kinase. Cell 72:269278.

Liu D , Chen X , Liu J , Ye J , Guo Z (2012) The rice ERF transcription factor OsERF922 negatively regulates resistance to Magnaporthe oryzae and salt tolerance. Journal of Experimental Botany 63:38993912.

Liu J , Ishitani M , Halfter U , Kim CS , Zhu JK (2000) The Arabidopsis thaliana SOS2 gene encodes a protein kinase that is required for salt tolerance. Proceedings of the National Academy of Sciences of the United States of America 97:37303734.

Liu S , Cheng Y , Zhang X , Guan Q , Nishiuchi S , Hase K , Takano T (2007) Expression of an NADP-malic enzyme gene in rice (Oryza sativa. L) is induced by environmental stresses; over-expression of the gene in Arabidopsis confers salt and osmotic stress tolerance. Plant Molecular Biology 64:4958.

Ma X , Qian Q , Zhu D (2005) Expression of a calcineurin gene improves salt stress tolerance in transgenic rice. Plant Molecular Biology 58:483495.

Mallikarjuna G , Mallikarjuna K , Reddy MK , Kaul T (2011) Expression of OsDREB2A transcription factor confers enhanced dehydration and salt stress tolerance in rice (Oryza sativa L.). Biotechnology Letters 33:16891697.

Miller J , McLachlan AD , Klug A (1985) Repetitive zinc-binding domains in the protein transcription factor IIIA from Xenopus oocytes. The EMBO Journal 4:16091614.

Mittal D , Chakrabarti S , Sarkar A , Singh A , Grover A (2009). Heat shock factor gene family in rice: Genomic organization and transcript expression profiling in response to high temperature, low temperature and oxidative stresses. Plant Physiology and Biochemistry 47(9):785795. doi: 10.1016/j.plaphy.2009.05.003.

Mizoi J , Shinozaki K , Yamaguchi-Shinozaki K (2011) AP2/ERF family transcription factors in plant abiotic stress responses. Biochimica et Biophysica Acta 1819:8696.

Motohashi T , Nagamiya K , Prodhan SH , Nakao K , Shishido T , Yamamoto Y , Moriwaki T , et al. (2010) Production of salt stress tolerant rice by overexpression of the catalase gene, katE, derived from Escherichia coli. Asia Pacific Journal of Molecular Biology and Biotechnology 18:1.

42 Mukhopadhyay A , Vij S , Tyagi AK (2004) Overexpression of a zinc-finger protein gene from rice confers tolerance to cold, dehydration, and salt stress in transgenic tobacco. Proceedings of the National Academy of Sciences of the United States of America 101:63096314.

Mller-Rber B , Ellenberg J , Provart N , Willmitzer L , Busch H , Becker D , Dietrich P , Hoth S , Hedrich R (1995) Cloning and electrophysiological analysis of KST1, an inward rectifying K+ channel expressed in potato guard cells. The EMBO Journal 14:24092416.

Mundy J , Chua NH (1988) Abscisic acid and water-stress induce the expression of a novel rice gene. The EMBO Journal 7:22792286.

Mustilli AC , Merlot S , Vavasseur A , Fenzi F , Giraudat J (2002) Arabidopsis OST1 protein kinase mediates the regulation of stomatal aperture by abscisic acid and acts upstream of reactive oxygen species production. Plant Cell 14:30893099.

Nakamura A , Fukuda A , Sakai S , Tanaka Y (2006) Molecular cloning, functional expression and subcellular localization of two putative vacuolar voltage-gated chloride channels in rice (Oryza sativa L.). Plant and Cell Physiology 47:3242.

Nakashima K , Tran LS , Van Nguyen D , Fujita M , Maruyama K , Todaka D , Ito Y , Hayashi N , Shinozaki K , Shinozaki KY (2007) Functional analysis of a NAC-type transcription factor OsNAC6 involved in abiotic and biotic stress-responsive gene expression in rice. Plant Journal 51:617630.

Nam MH , Huh SM , Kim KM , Park WJ , Seo JB , Cho K , Kim DY , Kim BG , Yoon IS (2012) Comparative proteomic analysis of early salt stress-responsive proteins in roots of SnRK2 transgenic rice. Proteome Science 10:25.

Nijhawan A , Jain M , Tyagi AK , Khurana JP (2008) Genomic survey and gene expression analysis of the basic leucine zipper transcription factor family in rice. Plant Physiology 146:333350.

Ning J , Li X , Hicks LM , Xiong L (2010) A raf-like MAPKKK gene DSM1 mediates drought resistance through reactive oxygen species scavenging in rice. Plant Physiology 152:876890.

Ogata K , Kanei-Ishii C , Sasaki M , Hatanaka H , Nagadoi A , Enari M , Nakamura H , Nishimura Y , Ishii S , Sarai A (1996) The cavity in the hydrophobic core of Myb DNA binding domain is reserved for DNA recognition and trans-activation. Nature Structural and Molecular Biology 3:178187.

Ogawa D , Yamaguchi K , Nishiuchi T (2007) High level overexpression of the Arabidopsis HsfA2 gene confers not only increased thermotolerance but also salt/osmotic stress tolerance and enhanced callus growth. Journal of Experimental Botany 58:111.

Ohta M , Hayashi Y , Nakashima A , Hamada A , Tanaka A , Nakamura T , Hayakawa T (2002) Introduction of a Na+/H+ antiporter gene from Atriplex gmelini confers salt tolerance to rice. FEBS Letters 532:279282.

Ouyang SQ , Liu YF , Liu P , Lei G , He SJ , Ma B , Zhang WK , Zhang JS , Chen SY (2010) Receptor-like kinase OsSIK1 improves drought and salt stress tolerance in rice (Oryza sativa) plants. Plant Journal 62:316 316.

Pabo CO , Peisach E , Grant RA (2001) Design and selection of novel Cys2His2 zinc finger proteins. Annual Review of Biochemistry 70:313340.

Pandey GK , Grant JJ , Cheong YH , Kim BG , Li L , Luan S (2005) ABR1, an APETALA2-domain transcription factor that functions as a repressor of ABA response in Arabidopsis. Plant Physiology 139:11851193.

Parre E , Ghars MA , Leprince AS , Thiery L , Lefebvre D , Bordenave M , Richard L , Mazars C , Abdelly C , Savour A. (2007) Calcium signaling via phospholipase C is essential for proline accumulation upon ionic but not nonionic hyperosmotic stresses in Arabidopsis. Plant

Physiology 144:503512.
Platten JD , Cotsaftis O , Berthomieu P , Bohnert H , Davenport RJ , Fairbairn DJ , Horie T , et al. (2006) Nomenclature for HKT transporters, key determinants of plant salinity tolerance. Trends in Plant Science 11:372374.
Qin F , Kakimoto M , Sakuma Y , Maruyama K , Osakabe Y , Tran LS , Shinozaki K , Yamaguchi-Shinozaki K (2007) Regulation and functional analysis of ZmDREB2A in response to drought and heat stresses in Zea mays L. Plant Journal 50:5469.
Ramakrishna A , Ravishankar GA (2011) Influence of abiotic stress signals on secondary metabolites in plants. Plant Signaling & Behavior 6:17201731.
Ramakrishna A , Ravishankar GA (2013) Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Climate Change and Plant Abiotic Stress Tolerance, N. Tuteja and S. S. Gill (Eds.). Wiley-VCH Verlag GmbH& Co. KGaA, Weinheim, Germany.
Rodriguez-Rosales MP , Jiang XY , Galvez FJ , Aranda MN , Cubero B , Venema K (2008) Overexpression of the tomato K+/H+ antiporter LeNHX2 confers salt tolerance by improving potassium compartmentalization. New Phytologist 179:366377.
Rosinski JA , Atchley WR (1998) Molecular evolution of the Myb family of transcription factors: Evidence for polyphyletic origin. Journal of Molecular Evolution 46:7483.
Schachtman DP , Munns R (1992) Sodium accumulation in leaves of triticum species that differ in salt tolerance. Australian Journal of Plant Physiology 25:239250.
Saijo Y , Hata S , Kyozuka J , Shimamoto K , Izui K (2000) Overexpression of a single Ca2+ dependent protein kinase confers both cold and salt/drought tolerance on rice plants. Plant Journal 23:319327.
Sakamoto A , Alia , Murata N (1998) Metabolic engineering of rice leading to biosynthesis of glycinebetaine and tolerance to salt and cold. Plant Molecular Biology 38:10111019.
Sakamoto H , Maruyama K , Sakuma Y , Meshi T , Iwabuchi M , Shinozaki K , Shinozaki KY (2004) Arabidopsis Cys2/His2-type zinc-finger proteins function as transcription repressors under drought, cold, and high-salinity stress conditions. Plant Physiology 136:27342746.
Sakuma Y , Maruyama K , Osakabe Y , Qin F , Seki M , Shinozaki K , Yamaguchi-Shinozaki K (2006) Functional analysis of an Arabidopsis transcription factor, DREB2A, involved in drought -responsive gene expression. Plant Cell 18:12921309.
Schmidt R , Schippers JHM , Welker A , Mieulet D , Guiderdoni E , Roeber BM (2012) Transcription factor OsHsfC1b regulates salt tolerance and development in Oryza sativa ssp. Japonica. AoB Plants doi:10.1093/aobpla/pls011.
Sentenac H , Bonneaud N , Minet M , Lacroute F , Salmon JM , Gaymard F , Grignon C (1992) Cloning and expression in yeast of a plant potassium ion transport system. Science 256:663665.
Shi H , Ishitani M , Kim C , Zhu JK (2000) The Arabidopsis thaliana salt tolerance gene SOS1 encodes a putative Na+/H+ antiporter. Proceedings of the National Academy of Sciences of the United States of America 97:68966901.
43 Shinozaki KY , Shinozaki K (2005) Organization of cis-acting regulatory elements in osmotic- and cold-stress-responsive promoters. Trends in Plant Science 10:8894.
Song SY , Chen Y , Chen J , Dai XY , Zhang WH (2011) Physiological mechanisms underlying OsNAC5-dependent tolerance of rice plants to abiotic stress. Planta 234:331345.
Sripinyowanich S , Klomsakul P , Boonburapong B , Bangyeekhun T , Asami T , Gu H , Buaboocha T , Chadchawan S (2010) Exogenous ABA induces salt tolerance in indica rice (Oryza sativa L.): The role of OsP5CS1 and OsP5CR gene expression during salt stress. Environmental and Experimental Botany 86:94105.
Sun SJ , Guo SQ , Yang X , Bao YM , Tang HJ , Sun H , Huang J , Zhang HS (2010) Functional analysis of a novel Cys2/His2-type zinc finger protein involved in salt tolerance in rice. Journal of Experimental Botany 61:28072818.
Takahashi S , Kimura S , Kaya H , Iizuka A , Wong HL , Shimamoto K , Kuchitsu K (2012) Reactive oxygen species production and activation mechanism of the rice NADPH oxidase OsRbohB. The Journal of Biochemistry 152:3743.
Takasaki H , Maruyama K , Kidokoro S , Ito Y , Fujita Y , Shinozaki K , Shinozaki KY , Nakashima K (2010) The abiotic stress-responsive NAC-type transcription factor OsNAC5 regulates stress-inducible genes and stress tolerance in rice. Molecular Genetics and Genomics 284:173183.
Tanaka Y , Hibin T , Hayashi Y , Tanaka A , Kishitani S , Takabe T , Yokota S , Takabe T (1999) Salt tolerance of transgenic rice overexpressing yeast mitochondrial Mn-SOD in chloroplasts. Plant Science 148:131138.
Tao Z , Kou Y , Liu H , Li X , Xiao J , Wang S (2011) OsWRKY45 alleles play different roles in abscisic acid signalling and salt stress tolerance but similar roles in drought and cold tolerance in rice. Journal of Experimental Botany 62:48634874.
Testerink C , Munnik T (2005) Phosphatidic acid: A multifunctional stress signaling lipid in plants. Trends in Plant Science 10:368375.
Thanaruksa R , Sripinyowanich S , Udomchalothorn T , Chadchawan S (2012) Effects of OsNUC1 motif on transgenic Arabidopsis thaliana L. growth under salt stress condition. Thai Journal of Botany 4:145157.
Tran LSP , Nakashima K , Sakuma Y , Simpson SD , Fujita Y , Maruyama K , Fujita M , Seki M , Kazuo Shinozaki K , Shinozaki KY (2004) Isolation and functional analysis of Arabidopsis stress-inducible NAC transcription factors that bind to a drought-responsive cis-element in the early responsive to dehydration stress 1 promoter. Plant Cell 16:24812498.
Tuteja N , Sopory SK (2008) Plant signaling in stress: G-protein coupled receptors, heterotrimeric G-proteins and signal coupling via phospholipases. Plant Signaling & Behavior 3:7986.
Venema K , Belver A , Marin-Manzano MC , Rodriguez-Rosales MP , Donaire JP (2003) A novel intracellular K+/H+ antiporter related to Na+/H+ antiporters is important for K+ ion homeostasis in plants. Journal of Biological Chemistry 278:2245322459.
Wang Q , Guan Y , Wu Y , Chen H , Chen F , Chu C (2008) Overexpression of a rice OsDREB1F gene increases salt, drought, and low temperature tolerance in both Arabidopsis and rice. Plant Molecular Biology 67:589602.
Welsch R , Wust F , Bar C , Babili SA , Beyer P (2008) A third phytoene synthase is devoted to abiotic stress-induced abscisic acid formation in rice and defines functional diversification of phytoene synthase genes. Plant Physiology 147:367380.
Wu L , Fan Z , Guo L , Li Y , Chen ZL , Qu LJ (2005) Overexpression of the bacterial nhaA gene in rice enhances salt and drought tolerance. Plant Science 168:297302.
Wu SJ , Ding L , Zhu JK (1996) SOS1, a genetic locus essential for salt tolerance and potassium acquisition. Pl ant Cell 8:617627.
Xia K , Wang R , Ou X , Fang Z , Tian C , Duan J , Wang Y , Zhang M (2012) OsTIR1 and OsAFB2 downregulation via OsmiR393 overexpression leads to more tillers, early flowering and less tolerance to salt and drought in rice. PLoS One 7(1):e30039. doi:10.1371/journal.pone.0030039.
Xiang Y , Huang Y , Xiong L (2007) Characterization of stress-responsive CIPK genes in rice for stress tolerance improvement. Plant Physiology 144:14161428.
Xiang Y , Tang N , Du H , Ye H , Xiong L (2008) Characterization of OsbZIP23 as a key player of the basic leucine zipper transcription factor family for conferring abscisic acid sensitivity and salinity and drought tolerance in rice. Plant Physiology 148:19381952.
Xiong L , Yang Y (2003) Disease resistance and abiotic stress tolerance in rice are inversely modulated by an abscisic acidinducible mitogen-activated protein kinase. Plant Cell 15:745759.
Xu D , Duan X , Wang B , Hong B , Ho Thd , Wu R (1996) Expression of a late embryogenesis abundant protein gene, hva1, from barley confers tolerance to water deficit and salt stress in transgenic rice. Plant Physiology 110:249257.

Xu DQ , Huang J , Guo SQ , Yang X , Bao YM , Tang HJ , Zhang HS (2008) Overexpression of a TFIIIA-type zinc finger protein gene ZFP252 enhances drought and salt tolerance in rice (Oryza sativa L.). FEBS Letters 582:10371043.

Xu GY , Rocha PSCF , Wang ML , Xu ML , Cui YC , Li LY , Zhu YX , Xia X (2011) A novel rice calmodulin-like gene, OsMSR2, enhances drought and salt tolerance and increases ABA sensitivity in Arabidopsis. Planta 234:4759.

Yamaguchi-Shinozaki K , Shinozaki K (2006) Transcriptional regulatory networks in cellular responses and tolerance to dehydration and cold stresses. Annual Review of Plant Biology 57:781803.

Yang A , Dai X , Zhang WH (2012) A R2R3-type MYB gene, OsMYB2, is involved in salt, cold, and dehydration tolerance in rice. Journal of Experimental Botany 63:25412556.

Ye H , Du H , Tang N , Li X , Xiong L (2009) Identification and expression profiling analysis of TIFY family genes involved in stress and phytohormone responses in rice. Plant Molecular Biology 71:291305.

Yoo JH , Park CY , Kim JC , Do Heo W , Cheong MS , Park HC , Kim MC , et al. (2005). Direct interaction of a divergent CaM isoform and the transcription factor, MYB2, enhances salt tolerance in Arabidopsis. Journal of Biological Chemistry 280:36973706.

Yoshida R , Hobo T , Ichimura K , Mizoguchi T , Takahashi F , Aronso J , Ecker JR , Shinozaki K (2002) ABA-activated SnRK2 protein kinase is required for dehydration stress signaling in Arabidopsis. Plant and Cell Physiology 43:14731483.

44 Yoshida R , Umezawa T , Mizoguchi T , Takahashi S , Takahashi F , Shinozaki K (2006) The regulatory domain of SRK2E/OST1/SnRK2.6 interacts with ABI1 and integrates abscisic acid (ABA) and osmotic stress signals. Journal of Biological Chemistry 281:53105318.

Yotsushima K , Mitsui T , Takaoka T , Hayakawa T , Igaue I (1993) Purification and characterization of membrane-bound inositol phospholipid-specific phospholipase C from suspension-cultured rice (Oryza sativa L.) cells. Plant Physiology 102:165172.

Zhang H , Zhai J , Mo J , Li D , Song F (2012) Overexpression of rice sphingosine-1-phosphate lyase gene OsSPL1 in transgenic tobacco reduces salt and oxidative stress tolerance. Journal of Integrative Plant Biology 54:652662.

Zhang HX , Blumwald E (2001) Transgenic salt-tolerant tomato plants accumulate salt in foliage but not in fruit. Nature Biotechnology 19:765768.

Zhang JZ , Creelman RA , Zhu JK (2004) From laboratory to field. Using information from Arabidopsis to engineer salt, cold, and drought tolerance in crops. Plant Physiology 135:615621.

Zhang Y , Andralojc PJ , Hey SJ , Primavesi LF , Specht M , Koehler J , Parry MAJ , Halford NG (2008) Arabidopsis sucrose nonfermenting-1-related protein kinase-1 and calcium-dependent protein kinase phosphorylate conserved target sites in ABA response element binding proteins. Annals of Applied Biology 153:401409.

Zhao F , Guo S , Zhang H , Zhao Y (2006a) Expression of yeast SOD2 in transgenic rice results in increased salt tolerance. Plant Science 170:216224.

Zhao F , Wang Z , Zhang Q , Zhao Y , Zhang H (2006b) Analysis of the physiological mechanism of salt-tolerant transgenic rice carrying a vacuolar Na+/H+ antiporter gene from Suaeda salsa. Journal of Plant Research 119:95104.

Zheng X , Chen B , Lu G , Han B (2009) Overexpression of a NAC transcription factor enhances rice drought and salt tolerance. Biochemical and Biophysics Research Communications 379:985989.

Zhu B , Su J , Chang M , Verma DPS , Fan YL , Wu R (1998) Overexpression of a 1-pyrroline-5-carboxylate synthetase gene and analysis of tolerance to water- and salt-stress in transgenic rice. Plant Science 139:4148.

Zhu JK (2001) Cell signaling under salt stress, water and cold stresses. Current Opinion in Plant Biology 5:401406.

Zhu JK (2002) Salt and drought stress signal transduction in plants. Annual Review of Plant Biology 53:247273.

Zhu Q , Zhang J , Gao X , Tong J , Xiao L , Li W , Zhang H (2010) The Arabidopsis AP2/ERF transcription factor RAP2.6 participates in ABA, salt and osmotic stress responses. Gene 457:112.

Zou M , Guan Y , Ren H , Zhang F , Chen F (2008) A bZIP transcription factor, OsABI5, is involved in rice fertility and stress tolerance. Plant Molecular Biology 66:675683.

Recent Advances on the Modulatory Role of ATPases toward Salt Tolerance in Plants

Anil VS , Rajkumar P , Kumar P , Mathew M.K. A plant Ca2+ pump, ACA2, relieves salt hypersensitivity in yeast. Modulation of cytosolic calcium signature and activation of adaptive Na+ homeostasis. J. Biol. Chem. 2008; 283: 34973506.

Barlet-Bas C , Khadouri C , Marsy S , Doucet A. Enhanced intracellular sodium concentration in kidney cells recruits a latent pool of Na-K-ATPase whose size is modulated by corticosteroids. J. Biol. Chem. 1990; 265: 77997803.

Blumwald E , Aharon GS , Apse M.P. Sodium transport in plant cells. Biochim. Biophys. Acta 2000; 1465: 140151.

Brown HD , Jackson RT , Dupuy H.J. Transport of sugar in Allium: Effects of inhibitors and ethylene. Nature 1964; 202: 722723.

Camoni L , Iori V , Marra M , Aducci P. Phosphorylation-dependent interaction between plant plasma membrane H+-ATPase and 14-3-3 proteins. J. Biol. Chem. 2000; 275: 99199923.

Chen HJ , Lin HW , Huang GJ , Lin Y.H. Sweet potato calmodulin SPCAM is involved in salt stress-mediated leaf senescence, H2O2 elevation and senescence-associated gene expression. J. Plant Physiol. 2012; 169: 18921902.

Chen J , Wang WH , Wu FH , He EM , Liu X , Shangguan ZP , Zheng H.L. Hydrogen sulfide enhances salt tolerance through nitric oxide-mediated maintenance of ion homeostasis in barley seedling roots. Sci. Rep. 2015; 5: 12516. doi:10.1038/srep12516.

Chen J , Xiao Q , Wu F , Dong X , He J , Pei Z , Zheng H. Nitric oxide enhances salt secretion and Na+ sequestration in a mangrove plant, Avicennia marina, through increasing the expression of H+-ATPase and Na+/H+ antiporter under high salinity. Tree Physiol. 2010; 30: 15701586.

Chen J , Xiong DY , Wang WH , Hu WJ , Simon M , Xiao Q , Liu TW , Liu X , Zheng H.L. Nitric oxide mediates root K+/Na+ Balance in a mangrove plant, Kandelia obovata, by enhancing the expression of AKT1-Type K+ channel and Na+/H+ antiporter under high salinity. PLoS One 2013; 8(8): e71543. doi:10.1371/journal.pone.0071543.

Chen Z , Pottosin II , Cuin TA , Fuglsang AT , Tester M , Jha D , Zepeda-Jazo I , et al. Root plasma membrane transporters controlling K+/Na+ homeostasis in salt-stressed barley. Plant Physiol. 2007; 145: 17141725.

Chinnusamy V , Jagendorf A , Zhu J.K. Understanding and improving salt tolerance in plants. Crop Sci. 2005; 45: 437448.

Chung WS , Lee SH , Kim JC , Do Heo W , Kim MC , Park CY , Park HC , et al. Identification of a calmodulin-regulated soybean Ca2+-ATPase (SCA1) that is located in the plasma membrane. Plant Cell 2000; 12: 13921407.

Conde A , Chaves MM , Gers H. Membrane transport, sensing and signaling in plant adaptation to environmental stress. Plant Cell Physiol. 2011; 52: 15831602.

Cram W.J. The effects of ouabain on sodium and potassium fluxes in excised roots of carrot. J. Exp. Bot. 1968; 19: 611616.

Cramer GR , Jones R.L. Osmotic stress and abscisic acid reduce cytosolic calcium activities in roots of Arabidopsis thaliana. Plant Cell Environ. 1996; 19: 12911298.

Cramer GR , Lynch J , Lauchli A , Epstein E. Influx of Na+, K+, and Ca2+ into roots of salt-stressed cotton seedlings. Plant Physiol. 1987; 83: 510516.
Davenport RJ , Tester M. A weakly voltage-dependent, nonselective cation channel mediates toxic sodium influx in wheat. Plant Physiol. 2000; 122: 823834.
David A. Involvement of nitric oxide and associated biomolecules in sunflower seedling growth in response to salt stress. PhD Thesis. 2012; University of Delhi, Delhi, India.
David A , Yadav S , Bhatla S.C. Sodium chloride stress induces nitric oxide accumulation in root tips and oil body surface accompanying slower oleosin degradation in sunflower seedlings. Physiol. Plant. 2010; 140: 342354.
Davis RF , Jaworski A.Z. Effects of ouabain and low temperature on the sodium efflux pump in excised corn roots. Plant Physiol. 1979; 63: 940946.
Ebrahimi R , Bhatla S.C. Ion distribution measured by electron probe X-ray microanalysis in apoplastic and symplastic pathways in root cells in sunflower plants grown in saline medium. J. Biosci. 2012; 37: 713721.
Felle HH , Tretyn A , Wagner G. The role of the plasma-membrane Ca2+-ATPase in Ca2+ homeostasis in Sinapis alba root hairs. Planta 1992; 188: 306313.
Flowers TJ , Galal HK , Bromham D.L. Evolution of halophytes: Multiple origins of salt tolerance in land plants. Funct. Plant Biol. 2010, 37: 604612.
Fortes P.A.G. Anthroylouabain: A specific fluorescent probe for the cardiac glycoside receptor of the Na-K ATPase. Biochemistry 1977; 16: 531540.
52 Gao D , Knight MR , Trewavas AJ , Sattelmacher B , Plieth C. Self-reporting Arabidopsis expressing pH and [Ca2+] indicators unveil ion dynamics in the cytoplasm and in the apoplast under abiotic stress. Plant Physiol. 2004; 134: 898908.
Geisler M , Axelsen KB , Harper JF , Palmgren M.G. Molecular aspects of higher plant P-type Ca2+-ATPases. Biochim. Biophys. Acta 2000; 1465: 5278.
Gwaudant F , Duby G , Stedingk E , Zhao R. Expression of a constitutively activated plasma membrane H+-ATPase alters plant development and increases salt tolerance. Plant Physiol. 2007; 144(August): 17631776.
Heermann R , Jung K. Stimulus perception and signaling in histidine kinases. In: Bacterial Signaling, Kramer R and Jung K (eds.). Wiley-VCH Verlag GmbH, Weinheim, 2010; pp. 135152.
Hernandez A , Cooke D , Clarkson D. In vivo activation of plasma membrane H+-ATPase hydrolytic activity by complex lipid-bound unsaturated fatty acids in Ustilago maydis. Eur. J. Biochem. 2002; 269: 10061011.
Hernandez M , Fernandez-Garcia N , Diaz-Vivancos P , Olmos E. A different role for hydrogen peroxide and the antioxidative system under short and long salt stress in Brassica oleracea roots. J. Exp. Bot. 2010; 61: 521535.
Hong Y , Pan X , Welti R , Wang X. The effect of phospholipase D3 on Arabidopsis response to hyperosmotic stress and glucose. Plant Signal. Behav. 2008; 3: 10991100.
Huda KM , Banu MS , Garg B , Tula S , Tuteja R , Tuteja N. OsACA6, a P-type IIB Ca2+ ATPase promotes salinity and drought stress tolerance in tobacco by ROS scavenging and enhancing the expression of stress-responsive genes. Plant J. 2013; 76, 9971015. doi:10.1111/tpj.12352.
Jaiswal J.K. Calciumhow and why? J. Biosci. 2001; 26: 357363.
Janicka-Russak M , Kabala K , Wdowikowska A , Kobus G. Modification of plasma membrane proton pumps in cucumber roots as an adaptation mechanism to salt stress. J. Plant Physiol. 2013; 170: 915922.
Janicka-Russak M , Kobus G. Modification of plasma membrane and vacuolar H+-ATPase in response to NaCl and ABA. J. Plant Physiol. 2007; 164: 295302.
Jiang Y , Yang B , Harris NS , Deyholos M.K. Comparative proteomic analysis of NaCl stress-responsive proteins in Arabidopsis roots. J. Exp. Bot. 2007; 58: 35913607.
Jurado LA , Chockalingam PS , Jarrett H.W. Apocalmodulin. Physiol. Rev. 1999; 79: 661682.
Kader A. Salt stress in rice: Adaptive mechanisms for cytosolic sodium homeostasis. PhD Thesis. 2006; Faculty of natural resources and agricultural sciences, Department of Plant Biology and Forest Genetics. Uppsala, Sweden.
Kader MA , Lindberg S , Seidel T , Golldack D, , Yemelyanov V. Sodium sensing induces different changes in free cytosolic calcium concentration and pH in salt-tolerant and salt-sensitive rice (Oryza sativa L.) cultivars. Physiol. Plant. 2007; 130: 99111.
Kasamo K. Regulation of plasma membrane H+-ATPase activity by the membrane environment. J. Plant Res. 2003; 116: 517523.
Kiegle E , Moore CA , Haseloff J , Tester MA , Knight M.R. Cell type specific calcium responses to drought, salt and cold in the Arabidopsis root. Plant J. 2000; 23: 267278.
Klobus G and Janicka-Russak M. Modulation by cytosolic components of proton pump activities in plasma membrane and tonoplast from Cucumis sativus roots during salt stress. Physiol. Plant. 2004; 121: 8492.
Knight H , Trewavas AJ , Knight M.R. Calcium signalling in Arabidopsis thaliana responding to drought and salinity. Plant J. 1997; 12: 10671078.
Li N , Li C , Chen S , Chang Y , Zhang Y , Wang R , Shi Y , Zheng X , Fritz E , Httermann A. Abscisic acid, calmodulin response to short term and long term salinity and the relevan ce to NaCl-induced antioxidant defense in two mangrove species. Open For. Sci. J. 2009; 2: 4858.
Lindberg S. Sucrose and ouabain effects on the kinetic properties of a membrane bound (Na+ + K+ + Mg2+) ATPase in sugar beet roots. Physiol. Plant. 1982; 54: 455460.
Lv DW , Li X , Zhang M , Gu AQ , Zhen SM , Wang C , Li XH , Yan Y.M. Large-scale phosphoproteome analysis in seedling leaves of Brachypodium distachyon L. BMC Genom. 2014; 15: 375. doi:10.1186/1471-2164-15-375.
Magdalena G , Maria S , Barbara G. Effect of short- and long-term salinity on the activities of antioxidative enzymes and lipid peroxidation in tomato roots. Acta Physiol. Plant. 2008; 30: 1118.
Martinez-Ballesta MC , Martinez V , Carvajal M. Aquaporin functionality in relation to H+-ATPase activity in root cells of Capsicum annuum grown under salinity. Physiol. Plant. 2003; 117(4): 413420.
Mser P , Gierth M , Schroeder J.I. Molecular mechanisms of potassium and sodium uptake in plants. Plant Soil 2002; 247: 4354.
Minorsky P.V. News from the archives: Do plants have ouabain (OU)-sensitive ATPases? Plant Physiol. 2002; 130: 45.
Morant-Avice AA , Jurvilliers P , Tremblin G , Coudret A. Effect of ouabain on stomatal movements and transpiration rate of Secale cereale. Biol. Plant 1997; 39: 235242.
Mukherjee S , Bhatla S.C. A novel fluorescence imaging approach to monitor salt stress-induced modulation of ouabain-sensitive ATPase activity in sunflower seedling roots. Physiol. Plant. 2014; 150: 540549.
Munns R , Tester M. Mechanisms of salinity tolerance. Annu. Rev. Plant Biol. 2008; 59: 651681.
Nassery H , Baker D.A. Extrusion of sodium ions by barley roots I. Characteristics of the extrusion mechanism. Ann. Bot. 1972; 36: 881887.
Olfatmiri H , Alemzadeh A , Zakipour Z. Up-regulation of plasma membrane H+-ATPase under salt stress may enable Aeluropus littoralis to cope with stress. Mol. Biol. Res. Commun. 2014; 3. 6775.

Oota Y. Removal of the sugar inhibition of flowering in Lemna gibba G3 by catecholamines. Plant Cell Physiol. 1974; 15: 6368.

Park KY , Jung JY , Park J , Hwang JU , Kim YW , Hwang I , Lee Y. A role for phosphatidylinositol 3-phosphate in abscisic acid-induced reactive oxygen species generation in guard cells. Plant Physiol. 2003; 132: 9298.

Perez-Prat E , Narashimhan ML , Binzel ML , Botella MA , Chen Z , Valpuesta V , Bressan RA , Hasegawa P.M. Induction of a putative Ca2-ATPase mRNA in NaCl adapted cells. Plant Physiol. 1992; 100: 14711478.

Pical C , Westergren T , Dove SK , Larsson C , Sommarin M. Salinity and hyperosmotic stress induce rapid increases in phosphatidylinositol 4,5-biphosphate, diacylglycerol pyrophosphate, and phosphatidyl choline in Arabidopsis thaliana cells. J. Biol. Chem. 1999; 274: 3823238240.

Pitan B , Schubert S , Mhling K. Decline in leaf growth under salt stress is due to an inhibition of H+ pumping activity and increase in apoplastic pH of maize leaves. J. Plant Nutr. Soil Sci. 2009; 172: 535543.

53 Qudeimat E , Faltusz AMC , Wheeler G , Lang D , Brownlee C , Reski R , Frank W. A PIIB-type Ca2+ ATPase is essential for stress adaptation in Physcomitrella patens. Proc. Natl. Acad. Sci. USA 2008; 105: 1955519560.

Reddy ASN , Ali GS , Celesnik H , Day I.S. Coping with stresses: Roles of calcium and calcium/calmodulin regulated gene expression. Plant Cell 2011; 23: 20102032.

Rhoads AR , Friedberg F. Sequence motifs for calmodulin recognition. FASEB J. 1997; 11: 331340.

Ruan HH , Shen WB , Xu L.L. Nitric oxide modulates the activities of plasma membrane ATPase and PPase in wheat seedling roots and promotes the salt tolerance against salt stress. Acta Bot. Sin. 2004; 46: 415422.

Saeng-ngam S , Takpirom W , Buaboocha T , Chadchawan S. The role of the OsCam1-1 salt stress sensor in ABA accumulation and salt tolerance in rice. J. Plant Biol. 2012; 55: 198208.

Sahu B , Shaw B. Salt-inducible isoform of plasma membrane H+-ATPase gene in rice remains constitutively expressed in natural halophyte, Suaeda maritima. J. Plant Physiol. 2009; 166: 10771089.

Schiefelbein JW , Shilpey A , Rowse P. Calcium influx at the tip of growing root-hair cells of Arabidopsis thaliana. Planta 1992; 187: 455459.

Sekmen AH , Bor M , Ozdemir F , Turkan I. Current concepts about salinity and salinity tolerance in plants. In: Climate Change and Plant Abiotic Stress Tolerance, Tuteja N and Gill SS (eds.), Volume 1. Wiley Blackwell, Singapore, 2010; pp. 163188.

Senatorov VV , Stys PK , Hu B. Regulation of Na+, K+-ATPase by persistent sodium accumulation in adult rat thalamic neurones. J. Physiol. 2000; 525: 343353.

Shabala S , Shabala L , Volkenburgh E.V. Calcium mediates root K+/Na+ homeostasis in poplar species differing in salt tolerance. Funct. Plant Biol. 2003; 30: 507514.

Shen P, Wang R , Zhang W. Rice phospholipase D is involved in salt tolerance by the mediation of H+-ATPase activity and transcription. J. Integr. Plant Biol. 2011; 53(4): 289299.

Shi H , Kim YS , Guo Y , Stevenson B , Zhu J.K. The Arabidopsis SOS5 locus encodes a putative cell surface adhesion protein and is required for normal cell expansion. Plant Cell 2003; 15: 1932.

Shi H , Lee B , Wu S-J , Zhu J.K. Overexpression of a plasma membrane Na+/H+ antiporter gene improves salt tolerance in Arabidopsis thaliana. Nat. Biotechnol. 2003; 21: 8185.

Shi H , Quintero FJ , Pardo JM , Zhu J.K. The putative plasma membrane Na+/H+ antiporter SOS1 controls long-distance Na+ transport in plants. Plant Cell 2002; 14: 465477.

Shi H , Zhu J.K. SOS4, a pyridoxal kinase gene, is required for root hair development in Arabidopsis. Plant Physiol. 2002; 129: 585593.

Shi Q , Ding F , Wang X , Wei M. Exogenous nitric oxide protect cucumber roots against oxidative stress induced by salt stress. Plant Physiol. Biochem. 2007; 45: 542550.

Sun H , Zhang L , Ren C , Chen C , Fan S , Xia J , Lin H , Hu C. The expression of Na+, K+-ATPase in Litopenaeus vannamei under salinity stress. Mar. Biol. Res. 2011; 7: 623628.

Sun J , Dai S , Wang R , Chen S , Li N , Zhou X , Lu C , et al. Calcium mediates root K+/Na+ homeostasis in poplar species differing in salt tolerance. Tree Physiol. 2009; 29: 11751186.

Tanaka K , Swanson SJ , Gilroy S , Stacey G. Extracellular nucleotides elicit cytosolic free calcium oscillations in Arabidopsis. Plant Physiol. 2010; 154: 705719.

Thomas D.A. The regulation of stomatal aperture in tobacco leaf epidermis strips: II. The effect of ouabain. Aust. J. Biol. Sci. 1970; 23: 981989.

Tikhaya NI , Mishutina N.E. Comparison of some membrane-bound ATPases of glycophytes and halophytes. Plant Soil 1981; 63: 2526.

Tuteja N. Integrated calcium signaling in plants. In: Signaling and Communication in Plants, Baluka F and Mancuso S (eds.). 2009 ; Springer, pp. 29 29.

Tuteja N. Mechanisms of high salinity tolerance in plants. Methods Enzymol. 2007; 428: 419438.

Tuteja N , Mahajan S. Calcium signaling network in plants: An overview. Plant Signal. Behav. 2007; 2: 7985; PMID: 19516972.

Vakhmistrov DB , Tikhaya NI , Mishutina N.E. Characterization and comparison of membrane-bound Na,K,Mg-ATPase from tissues of Hordeum vulgare L. and Halocnemum strobilaceum L. Physiol. Plant. 1982, 55: 155160.

Vitart V , Baxter I , Doerner P , Harper J.F. Evidence for a role in growth and salt resistance of a plasma membrane H+-ATPase in the root endodermis. Plant J. 2001; 27: 191201.

Wakeel A , Hanstein S , Pitann B , Schubert S. Hydrolytic and pumping activity of H+-ATPase from leaves of sugar beet (Beata vulgaris L.) as affected by salt stress. J. Plant Physiol. 2010; 167: 725731.

Wang H , Liang X , Wan Q , Wang X , Bi Y. Ethylene and nitric oxide are involved in maintaining ion homeostasis in Arabidopsis callus under salt stress. Planta 2009; 230: 293307.

Wang J , Adachi M , Rhoads D.E. A calnaktin-like inhibitor of Na+, K+-ATPase in rat brain: Regulation of 1 and 2 isozymes. Comp. Biochem. Physiol. 1998; 119B: 241246.

Watanabe S. Ouabain and IAA effects on Mimosa pudica. Artes Liberals Iwate Univ. 1971; 8: 7580.

White PJ , Broadley M.R. Calcium in plants. Ann. Bot. 2003; 92: 487511.

Wimmers LE , Ewing NN , Bennett A.B. Higher plant Ca2+-ATPase: Primary structure and regulation of mRNA abundance by salt. Proc. Natl. Acad. Sci. USA 1992; 89: 92059209.

Wu J , Seliskar D.M. Salinity adaptation of plasma membrane H+-ATPase in the salt marsh plant Spartina patens: ATP hydrolysis and enzyme kinetics. J. Exp. Bot. 1998; 49: 10051013.

Yingst DR , Ye-Hu J , Chen H , Barret V. Calmodulin increases Ca-dependent inhibition of the Na,K-ATPase in human red blood cells. Arch. Biochem. Biophys. 1992; 295: 4954.

Zhang J , Davies W.J. Changes in the concentration of ABA xylem sap as a function of changing soil water status will account for changes in leaf conductance. Plant Cell Environ. 1990; 13: 277285.

Zhang M , Fang Y , Liang Z , Huang L. Enhanced expression of vacuolar H+-ATPase subunit E in the roots is associated with the adaptation of Broussonetia papyrifera to salt stress. PLoS One 2012; 7(10): e48183.

Zhang YK , Han XJ , Chen XL , Hong J , Cui X.M. Exogenous nitric oxide on antioxidative system and ATPase activities from tomato seedlings under copper stress. Sci. Hortic. 2009; 123: 217223.
Zhang YY , Wang LL , Liu YL , Zhang Q , Wei QP , Zhang W.H. Nitric oxide enhances salt tolerance in maize seedlings through increasing activities of proton-pump and Na1/H1 antiport in the tonoplast. Planta 2006; 224: 545555.
Zhao L , Zhang F , Guo J , Yang Y , Li B , Zhang L. Nitric oxide functions as a signal in salt resistance in the calluses from two ecotypes of reed. Plant Physiol. 2004; 134: 849857. doi:10.1104/pp.103. 030023.
54 Zhu J , Lee BH , Dellinger M , Cui X , Zhang C , Wu S , Nothnage EA , Zhu J.K. A cellulose synthase-like protein is required for osmotic stress tolerance in Arabidopsis. Plant J. 2010; 63: 128140
Zhu J.K. Genetic analysis of plant salt tolerance using Arabidopsis. Plant Physiol. 2000; 124: 941948.
Zhu J.K. Plant salt tolerance. Trend. Plant Sci. 2001; 6: 6671.
Zhu J.K. Regulation of ion homeostasis under salt stress. Curr. Opin. Plant Biol. 2003; 6: 441445.
Zhu J.K. Salt and drought stress signal transduction in plants. Annu. Rev. Plant Biol. 2002; 53: 247273.
Zhu X , Feng Y , Liang G , Liu N , Zhu JK . Aequorin-based luminescence imaging reveals stimulus- and tissue-specific Ca2+ dynamics in Arabidopsis plants. Mol. Plant. 2013; 6: 444455.

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Adams S , Cockshull K , Cave C. Effect of temperature on the growth and development of tomato fruits. Ann. Bot. 2001;88:869877.
Ahuja I , De Vos Rch , Bones AM , Hall R.D. Plant molecular stress responses face climate change. Trends Plant Sci. 2010;15(12):664674.
Apel K , Hirt H. Reactive oxygen species: Metabolism, oxidative stress, and signal transduction. Ann. Rev. Plant Biol. 2004;55:373399.
Argyris J , Dahal P , Hayashi E , Still DW , Bradford K.J. Genetic variation for lettuce seed thermoinhibition is associated with temperature-sensitive expression of abscisic acid, gibberellin, and ethylene biosynthesis, metabolism, and response genes. Plant Physiol. 2008;148:926947.
Argyris J , Truco MJ , Ochoa O , McHale L , Dahal P , VanDeynze A , Michelmore RW , Bradford K.J. A gene encoding an abscisic acid biosynthetic enzyme (LsNCED4) collocates with the high temperature germination locus Htg6.1 in lettuce (Lactuca sp.). Theor. Appl. Genet. 2011; 122:95108.
Atkin OK , Bruhn D , Hurry VM , Tjoelker M.G. Evans Review No. 2: The hot and the cold: Unravelling the variable response of plant respiration to temperature. Funct. Plant Biol. 2005;32(2):87105.
Bai J. Genetic variation of heat tolerance and correlation with other agronomic traits in a maize (Zea mays L.) recombinant inbred line population. Available at: http://hdl.handle.net/2346/13572. 2011.
Balasubramanian S , Sureshkumar S , Lempe J , Weigel D. Potent induction of Arabidopsis thaliana flowering by elevated growth temperature. Plos Genet. 2006;2:980989.
Barua D , Heckathorn SA , Coleman J.S. Variation in heat-shock proteins and photosynthetic thermotolerance among natural populations of Chenopodium album L. from contrasting thermal environments: Implications for plant responses to global warming. J. Integr. Plant Biol. 2008;50:14401451.
Battisti DS , Naylor R.L. Historical warnings of future food insecurity with unprecedented seasonal heat. Science 2009;323:240244.
Benites FRG , Pinto C.A.B.P. Genetic gains for heat tolerance in potato in three cycles of recurrent selection. Crop Breed. Appl. Biotechnol. 2011;11:133140.
Blum A . Drought resistanceIs it really a complex trait? Functional Plant Biology 2011;38(10):753757.
Cattivelli L , Rizza F , Badeck FW , Mazzucotelli E , Mastrangelo AM , Francia E , Mar C , Tondelli A , Stanca A.M. Drought tolerance improvement in crop plants: An integrated view from breeding to genomics. Field Crops Res. 2008;105:114.
Challinor AJ , Watson J , Lobell DB , Howden SM , Smith DR , Chhetri N. A meta-analysis of crop yield under climate change and adaptation. Nat. Clim. Change 2014;4(4):287.
Cleland EE , Allen JM , Crimmins TM , Dunne JA , Pau S , Travers SE , Zavaleta ES , Wolkovich E.M. Phenological tracking enables positive species responses to climate change. Ecology 2012;93:17651771.
Cleland EE , Chuine I , Menzel A , Mooney HA , Schwartz M.D. Shifting plant phenology in response to global change. Trends Ecol. Evol. 2007;22(7):357365.
Collins NC , Tardieu F , Tuberosa R . Quantitative trait loci and crop performance under abiotic stress: Where do we stand? Plant Physiol. 2008;144:469486.
Coote PJ , Cole MB , Holyoak C. Thermal inactivation of Listeria monocytogenes during a process simulating temperatures achieved during microwave heating. J. Appl. Bacteriol. 1991;70(6):489494.
Cottee N , Tan D , Bange M , Cothren J , Campbell L. Multi-level determination of heat tolerance in cotton (Gossypium hirsutum L.) under field conditions. Crop Sci. 2010;50:25532564.
Daux V , Garcia De Cortazar-Atauri I , Yiou P , Chuine I , Garnier E , Le Roy Ladurie E , Mestre O , Tardaguila J . An open-access database of grape harvest dates for climate research: Data description and quality assessment. Clim. Past 2012;8:14031418.
Devasirvatham V , Tokachichu RN , Trethowan RM , Tan DKY , Gaur PM , Mallikarjuna N. Effect of high temperature on the reproductive development of chickpea genotypes under controlled environments. Funct. Plant Biol. 2012;39:10091018.
Ditta A. Salt tolerance in cereals: Molecular mechanisms and applications. In: Molecular Stress Physiology of Plants, Rout GR , Das AB (Eds.). Springer, India; 2013, pp. 133154.
Don AA , Miranda GV , DeLima RO , Chaves LG , eGama EEG. Genetic parameters and predictive genetic gain in maize with modified recurrent selection method. Chilean J. Agric. Res. 2012;72:1:33.
Duran C , Eales D , Marshall D , Imelfort M , Stiller J , Berkman PJ , Clark T , et al. Future tools for association mapping in crop plants. Genome 2010;53(1):10171023.
Field CB , Barros VR , Mach K , Mastrandrea M . Climate change 2014: Impacts, adaptation, and vulnerability, vol. V. New York: Cambridge University Press Cambridge; 2014.
Godfray HCJ , Beddington JR , Crute IR , Haddad L , Lawrence D , Muir JF , Pretty J , Robinson S , Thomas SM , Toulmin C. Food security: The challenge of feeding 9 billion people. Science 2010;327:812818.
Gordo O , Sanz J.J. Impact of climate change on plant phenology in Mediterranean ecosystems. Global Change Biol. 2010;16:10821106.
Guilioni L , Wry J , Lecoeur J. High temperature and water deficit may reduce seed number in field pea purely by decreasing plant growth rate. Funct. Plant Biol. 2003;30:11511164.
Guy RD , Vanlerberghe G.C. Partitioning of respiratory electrons in the dark in leaves of transgenic tobacco with modified levels of alternative oxidase. Physiol. Plant. 2005;125(2):171180.

Habier D , Fernando RL , Dekkers J.C.M. Genomic selection using low-density marker panels. Genetics 2009;182:343353.
Hall A.E. Breeding cowpea for future climates. In: Crop Adaptation to Climate Change, Yadav SS , Redden R , Hatfield JL , Lotze-Campen H , Hall AJW (Eds.). John Wiley & Sons, Hoboken; 2011.
Heffner EL , Sorrells ME , Jannin k J.L. Genomic selection for crop improvement. Crop Sci. 2009;49:112.
Hirayama T , Shinozaki K. Research on plant abiotic stress responses in the post-genome era: Past, present and future. Plant J. 2010;61:10411052.
Hong SW , Lee U , Vierling E. Arabidopsis hot mutants define multiple functions required for acclimation to high temperatures. Plant Physiol. 2003;132:757767.
IPCC. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon S , Qin D , Manning M , Chen Z , Marquis M , Averyt KB , Tignor M , Miller HL (Eds.). Cambridge University Press, Cambridge, UK; 2007.
61 IPCC. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri RK , and Meyer LA (Eds.)]. IPCC, Geneva, Switzerland; 2014, p. 151.
IPCC. Working Group I Contribution to the IPCC Fifth Assessment Report on Climate Change 2013: The Physical Science Basis, Summary for Policymakers. 2013. www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf
Jagadish SVK , Craufurd PQ , Shi W , Oane R. A phenotypic marker for quantifying heat stress impact during microsporogenesis in rice (Oryza sativa L.). Funct. Plant Biol. 2013;41:4855.
Jagadish SVK , Muthurajan R , Oane R , Wheeler TR , Heuer S , Bennett J , Craufurd P.Q. Physiological and proteomic approaches to address heat tolerance during anthesis in rice (Oryza sativa L.). J. Exp. Bot. 2010;61:143 143.
Jagadish SVK , Muthurajan R , Rang ZW , Malo R , Heuer S , Bennett J , Craufurd P.Q. Spikelet proteomic response to combined water deficit and heat stress in rice (Oryza sativa cv. N22). Rice 2011;4:111.
Jiang Y , Lahlali R , Karunakaran C , Kumar S , Davis AR , Bueckert R.A. Seed set, pollen morphology and pollen surface composition response to heat stress in field pea. Plant Cell Environ. 2015;38(1):23872397.
Jones G.V. Climate change and wine: Observations, impacts and future implications. Aust. N. Z. Wine Ind. J. 2006;21:2126.
Julien Y , Sobrino J.A. Global land surface phenology trends from GIMMS database. Int. J. Remote Sens. 2009;30:34953513.
Khorsand RR , Oberbauer SF , Starr G , Puma IPL , Pop E , Ahlquist L , Baldwin T. Plant phenological responses to a longterm experimental extension of growing season and soil warming in the tussock tundra of Alaska. Global Change Biol. 2015;21(12):45204532.
Larkindale J , Vierling E. Core genome responses involved in acclimation to high temperature. Plant Physiol. 2008;146:748761.
Li X , Zhang GQ , Sun B , Zhang S , Zhang YQ , Liao YWK , Zhou YH , Xia XJ , Shi K , Yu J.Q. Stimulated leaf dark respiration in tomato in an elevated carbon dioxide atmosphere. Sci. Rep. 2013;3:18.
Lin MY , Chai KH , Ko SS , Kuang LY , Lur HS , Charng Y.Y. A positive feedback loop between Heat Shock Protein101 and Heat Stress-Associated 32-Kd Protein modulates long-term acquired thermotolerance illustrating diverse heat stress responses in rice varieties. Plant Physiol. 2014;164:20452053.
Long BM , Bahar NHA , Atkin O.K. Contributions of photosynthetic and non-photosynthetic cell types to leaf respiration in Vicia faba L. and their responses to growth temperature. Plant Cell Environ. 2015;38:22632276.
Lopes MS , Reynolds M.P. Partitioning of assimilates to deeper roots is associated with cooler canopies and increased yield under drought in wheat. Funct. Plant Biol. 2010;37:147156.
Mareov L , Sychrov H. Genetic interactions among the Arl1GTPase and intracellular Na+/H+ antiporters in pH homeostasis and cation detoxification. FEMS Yeast Res. 2010;10:802811.
Mason RE , Mondal S , Beecher FW , Pacheco A , Jampala B , Ibrahim AM , Hays D.B. QTL associated with heat susceptibility index in wheat (Triticum aestivum L.) under short-term reproductive stage heat stress. Euphytica 2010;174, 423436.
Molinier J , Ries G , Zipfel C , Hohn B. Transgeneration memory of stress in plants. Nature 2006;442:10461049.
Morgante M , Salamini F. From plant genomics to breeding practice. Curr. Opin. Biotechnol. 2003;14:214219.
Nakashima K , Tran LSP , Van Nguyen D , Fujita M , Maruyama K , Todaka D , Ito Y , Hayashi N , Shinozaki K , YamaguchiShinozaki K. Functional analysis of a NAC-type transcription factor OsNAC6 involved in abiotic and biotic stress-responsive gene expression in rice. Plant J. 2007;51:617630.
Ogweno J , Song X , Shi K , Hu W , Mao W , Zhou Y , Yu J , Nogues S. Brassinosteroids alleviate heat-induced inhibition of photosynthesis by increasing carboxylation efficiency and enhancing antioxidant systems in Lycopersicon esculentum. J. Plant Growth Regul. 2008;27:4957.
Paliwal R , Rder MS , Kumar U , Srivastava J , Joshi A.K. QTL mapping of terminal heat tolerance in hexaploid wheat (T. aestivum L.). Theor. Appl. Genet. 2012;125:561575.
Petkova V , Nikolova V , Kalapchieva SH , Stoeva V , Topalova E , Angelova S. Physiological response and pollen viability of Pisum sativum genotypes under high temperature influence. Acta Hort. 2009;830:665674.
Pinto RS , Reynolds MP , Mathews KL , McIntyre CL , Olivares-Villegas JJ , Chapman S.C. Heat and drought adaptive QTL in a wheat population designed to minimize confounding agronomic effects. Theor. Appl. Genet. 2010;121:10011021.
Prasad P , Boote K , Allen L , Sheehy J , Thomas J. Species, ecotype and cultivar differences in spikelet fertility and harvest index of rice in response to high temperature stress. Field Crops Res. 2006;95:398411.
Prasad P , Pisipati S , Mutava R , Tuinstra M. Sensitivity of grain sorghum to high temperature stress during reproductive development. Crop Sci. 2008;48:19111917.
Pudas E , Leppl M , Tolvanen A , Poikolainen J , Venlinen A , Kubin E. Trends in phenology of Betula pubescens across the boreal zone in Finland. Int. J. Biometeorol. 2008;52(4):251259.
Qaderi MM , Kurepin LV , Reid D.M. Growth and physiological responses of canola (Brassica napus) to three components of global climate change: Temperature, carbon dioxide and drought. Physiol. Plant. 2006;128:710721.
Raju BR , Narayanaswamy BR , Mohankumar MV , Sumanth KK , Rajanna MP , Mohanraju B , Udayakumar M , Sheshshayee M.S. Root traits and cellular level tolerance hold the key in maintaining higher spikelet fertility of rice under water limited conditions. Funct. Plant Biol. 2014;41:930939.
Ramakrishna A , Ravishankar G.A. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal. Behav. 2011;6:17201731.
Ramakrishna A , Ravishankar G.A. Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Climate Change and Plant Abiotic Stress Tolerance, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany; 2013, pp. 705 705.
Ramalho MAP , Abreu FB , Santos JB . Genetic progress after four cycles of recurrent selection for yield and grain traits in common bean. Euphytica 2005;144:2329.
Rang ZW , Jagadish SVK , Zhou QM , Craufurd PQ , Heuer S. Effect of heat and drought stress on pollen germination and spikelet fertility in rice. Environ. Exp. Bot. 2011;70:5865.

Rizhsky L , Liang H , Shuman J , Shulaev V , Davletova S , Mittler R. When defense pathways collide: The response of Arabidopsis to a combination of drought and heat stress. Plant Physiol. 2004;134:16831696.
Roy SJ , Tucker EJ , Tester M. Genetic analysis of abiotic stress tolerance in crops. Curr. Opin. Plant Biol. 2011;14:232239.
62 Ruml M , Kora N , Vujadinovi M , Vukovi A , Ivanievi D. Response of grapevine phenology to recent temperature change and variability in the wine-producing area of Sremski Karlovci, Serbia. J. Agric. Sci. 2016;154(2):186206.
Sadras VO , Lake L, , Chenu K, , McMurray LS , Leonforte A. Water and thermal regimes for field pea in Australia and their implications for breeding. Crop Pasture Sci. 2012;63:3344.
Sadras VO , Petrie P.R. Climate shifts in southeastern Australia: Early maturity of Chardonnay, Shiraz and Cabernet-Sauvignon is associated with early onset rather than faster ripening. Aust. J. Grape Wine Res. 2011;17:199205.
Salem MA , Kakani VG , Koti S , Reddy K.R. Pollen-based screening of soybean genotypes for high temperatures. Crop Sci. 2007;47:219231.
Scafaro AP , Haynes PA , Atwell B.J. Physiological and molecular changes in Oryza ameridionalis Ng., a heat-tolerant species of wild rice. J. Exp. Bot. 2010;61:191202.
Schwartz MD , Ahas R , Aasa A. Onset of spring starting earlier across the Northern Hemisphere. Global Change Biol. 2006;12:343351.
Selvaraj MG , Burow G , Burke JJ , Belamkar V , Puppala N , Burow M.D. Heat stress screening of peanut (Arachis hypogaea L.) seedlings for acquired thermotolerance. Plant Growth Regul. 2011;65:8391.
Senthil-Kumar M , Udayakumar M. Development of thermotolerant tomato (Lycopersicon esculentum Mill.) lines: An approach based on mutagenesis. India J. Plant Biol. 2004;31:139148.
Shah N , Paulsen G. Interaction of drought and high temperature on p hotosynthesis and grain-filling of wheat. Plant Soil 2003;257:219226.
Shanmugam S , Kjaer KH , Ottosen CO , Rosenqvist E , Kumari SD , Wollenweber B. The alleviating effect of elevated CO2 on heat stress susceptibility of two wheat (Triticum aestivum L.) cultivars. J. Agron. Crop Sci. 2013;199:340350.
Shi W , Lawas LMF , Raju BR , Jagadish S.V.K. Acquired thermotolerance and transgenerational heat stress response at flowering in rice. J. Agron. Crop Sci. 2016;202(4):309319.
Singh RK , Redoa E , Refuerzo L. Varietal improvement for abiotic stress tolerance in crop plants: Special reference to salinity in rice. In: Abiotic Stress Adaptation in Plants, Gonzalez Fontes A (Ed.). Studium Press Llc, Houston; 2010, pp. 387415.
Sivasankar S , Williams RW , Greene T.W. Abiotic stress tolerance in plants: An industry perspective. In: Improving Crop Resistance to Abiotic Stress, Tuteja N , Gill SS , Tiburcio AF , Tuteja R (Eds.). Wiley-Blackwell, Hoboken; 2012, pp. 2747.
Snape J , Butterworth K , Whitechurch E , Worland AJ . Waiting for fine times: Genetics of flowering time in wheat. In: Wheat in a Global Environment. Developments in Plant Breeding, Bed Z, Lng L (Eds.) vol 9. Springer, Dordrecht; 2001, pp. 6774.
Soemphol W , Deeraksa A , Matsutani M , Yakushi T , Toyama H , Adachi O , Yamada M, , Matsushita K. Global analysis of the genes involved in the thermotolerance mechanism of thermotolerant Acetobacter tropicalis SKU1100. Biosci. Biotechnol. Biochem. 2011;75:19211928.
Soemphol W , Tatsuno M , Okada T , Matsutani M , Kataoka N , Yakushi T , Matsushita K. A novel Na+(K+)/H+ antiporter plays an important role in the growth of Acetobacter tropicalis SKU1100 at high temperatures via regulation of cation and pH homeostasis. J. Biotechnol. 2015;211:4655.
Souza MA , Pimentel AJB , Ribeiro G. Breeding for heat-stress tolerance. In: Plant Breeding for Abiotic Stress Tolerance, Fritsche-Neto R , Borm A (Eds.). Springer, Berlin; 2012, pp. 137156.
Springate DA , Kover P.X. Plant responses to elevated temperatures: A field study on phenological sensitivity and fitness responses to simulated climate warming. Global Change Biol. 2014;20(2):456465.
Stavang JA , Gallego-Bartolome J , Gomez MD , Yoshida S , Asami T , Olsen JE , Garcia-Martinez JL , Alabadi D , Blazquez M.A. Hormonal regulation of temperature-induced growth in Arabidopsis. Plant J. 2009;60:589601.
Suter L , Widmer A. Environmental heat and salt stress induce transgenerational phenotypic changes in Arabidopsis thaliana. PLoS One 2013;8:e60364.
Suzuki N , Mittler R. Reactive oxygen species and temperature stresses: A delicate balance between signaling and destruction. Physiol. Plant. 2006;126:4551.
Takeda S , Matsuoka M. Genetic approaches to crop improvement: Responding to environmental and population changes. Nat. Rev. Genet. 2008;9:444457.
Teixeira EI , Fischer G , van Velthuizen H , Walter C , Ewert F. Global hot-spots of heat stress on agricultural crops due to climate change. Agric. For. Meteorol. 2013;170:206-215.
Tester M , Langridge P. Breeding technologies to increase crop production in a changing world. Science 2010;327:818822.
Thomson MJ , deOcampo M , Egdane J , Rahman MA , Sajise AG , Adorada DL , Tumimbang-Raiz E , et al. Characterizing the Saltol quantitative trait locus for salinity tolerance in rice. Rice 2010;3:148160.
Tomasi D , Jones GV , Giust M , Lovat L , Gaiotti F. Grapevine phenology and climate change: Relationships and trends in the Veneto Region of Italy for 19642009. Am. J. Enol. Vitic. 2011;62:329339.
Varshney RK , Nayak SN , May GD , Jackson S.A. Next-generation sequencing technologies and their implications for crop genetics and breeding. Trends Biotechnol. 2009;27:522530.
Vijayalakshmi K , Fritz AK , Paulsen GM , Bai G , Pandravada S , Gill B.S. Modeling and mapping QTL for senescence-related traits in winter wheat under high temperature. Mol. Breed. 2010;26:163175.
Vos P , Hogers R , Bleeker M , Reijans M , vandeLee T , Hornes M , Friters A , et al. AFLP: A new technique for DNA finger printing. Nucl. Acids Res. 1995;23:44074414.
Wahid A , Gelani S , Ashraf M , Foolad M.R. Heat tolerance in plants: An overview. Environ. Exper. Bot. 2007;61:199223.
Wang W , Vinocur B , Shoseyov O , Altman A. Role of plant heat-shock proteins and molecular chaperones in the abiotic stress response. Trends Plant Sci. 2004;9:244252.
Wang X , Cai J , Liu F , Jin M , Yu H , Jiang D , Wollenweber B , Dai T , Cao W. Pre-anthesis high temperature acclimation alleviates the negative effects of postanthesis heat stress on stem stored carbohydrates remobilization and grain starch accumulation in wheat. J. Cereal Sci. 2012;55:331336.
Wang X , Dinler BS , Vignjevic M , Jacobsen S , Wollenweber B. Physiological and proteome studies of responses to heat stress during grain filling in contrasting wheat cultivars. Plant Sci. 2015;230:3350.
Webb LB , Whetton PH, , Barlow E.W.R. Observed trends in winegrape maturity in Australia. Global Change Biol. 2011;17:27072719.
Weitzel G , Pilatus U , Rensing L. The cytoplasmic pH, ATP content and total protein synthesis rate during heat-shock protein inducing treatments in yeast. Exp. Cell Res. 1987;170:6479.
Wigge P.A. Ambient temperature signalling in plants. Curr. Opin. Plant Biol. 2013;16:661666.
63 Wollenweber B , Porter JR , Schellberg J. Lack of interaction between extreme high-temperature events at vegetative and reproductive growth stages in wheat. J. Agron. Crop Sci. 2003;189:142150.

Xu J , Duan X , Yang J , Beeching JR , Zhang P. Enhanced reactive oxygen species scavenging by overproduction of superoxide dismutase and catalase delays postharvest physiological deterioration of cassava storage roots. Plant Physiol. 2013;161(3):15171528.
Xu Z , Shimizu H , Yagasaki Y , Ito S , Zheng Y , Zhou G. Interactive effects of elevated CO2, drought, and warming on plants. J. Plant Growth Regul. 2013;32:692707.
Ye C , Argayoso MA , Redoa ED , Sierra SN , Laza MA , Dilla CJ , Mo Y , et al. Mapping QTL for heat tolerance at flowering stage in rice using SNP markers. Plant Breed. 2012;131:3341.
Young LW , Wilen RW , Bonham-Smith P.C. High temperature stress of Brassica napus during flowering reduces micro- and megagametophyte fertility, induces fruit abortion, and disrupts seed production. J. Exp. Bot. 2004;55:485495.
Yu J , Yang Z , Jespersen D , Huang B. Photosynthesis and protein metabolism associated with elevated CO2 mitigation of heat stress damages in tall fescue. Environ. Exp. Bot. 2014;99:7585.
Zhang WB , Jiang H , Qiu PC , Liu CY , Chen FL , Xin DW , Li CD , Hu GH , Chen Q.S. Genetic overlap of QTL associated with low-temperature tolerance at germination and seedling stage using BILs in soybean. Can. J. Plant Sci. 2012;92:18.

Biochemical and Molecular Mechanisms of HighTemperature Stress in Crop Plants

Ahmad, P. , Prasad, M.N.V. 2012. Environmental Adaptations and Stress Tolerance of Plants in the Era of Climate Change. New York, NY: Springer, pp. 297324.
Allen, L.H. , Baker, J.T. , Albrecht, S.L. , Boote, K.J. , Pan, D. , Vu, J.C.V. 1995. Carbon dioxide and temperature effects on rice. In: Peng S , Ingram KT , Neue H-U , Ziska LH , eds. Climate Change and Rice. Berlin: Springer, pp. 258277.
Apel, K. , Hirt, H. 2004. Reactive oxygen species: Metabolism, oxidative stress, and signal transduction. Annu. Rev. Plant Biol. 55:373399.
Asthir, B. 2015a. Mechanisms of heat tolerance in crop plants. Biol. Plant. 59:620628.
Asthir, B. 2015b. Protective mechanisms of heat tolerance in crop plants. J. Plant Interact. 10:202210.
Bai, J. 2011. Genetic variation of heat tolerance and correlation with other agronomic traits in a maize (Zea mays L.) recombinant inbred line population. Available from: http://hdl.handle.net/2346/13572.
Battaglia, M , Covarrubias, A.A. 2013. Late embryogenesis abundant (LEA) proteins in legumes. Front. Plant Sci. 4:190.
Bhattacharjee, S. 2012. The language of reactive oxygen species signalling in plants. J. Bot. 22:985298.
Bita, C.E. , Gerats, T. 2013. Plant tolerance to high temperature in a changing environment: Scientific fundamentals and production of heat stress-tolerant crops. Front. Plant Sci. 4:273.
Bita, C.E. , Zenoni, S. , Vriezen, W.H. , Mariani, C. , Pezzotti, M. , Gerats, T. 2011. Temperature stress differentially modulates transcription in meiotic anthers of heat-tolerant and heat-sensitive tomato plants. BMC Genom. 12:384.
Bohnert, H.J. , Gong, Q. , Li, P. , Ma, S. 2006. Unravelling abiotic stress tolerance mechanismsgetting genomics going. Curr. Opin. Plant Biol. 9:180188.
Bokszczanin, K.L. , Fragkostefanakis, S. 2013. Perspectives on deciphering mechanisms underlying plant heat stress response and thermotolerance. Front. Plant Sci. 4:315.
Bonneau, J. , Taylor, J. , Parent, B. 2013. Multi-environment analysis and improved mapping of a yield-related QTL on chromosome 3B of wheat. Theor. Appl. Genet. 126:747761.
Brini, F. , Saibi, W. , Amara, I. , Gargouri, A. , Masmoudi, K., Hanin, M. 2010. The wheat dehydrin DHN-5 exerts a heat-protective effect on beta-glucosidase and glucose oxidase activities. Biosci. Biotech. Biochem. 74:10501054.
Chakraborty, U. , Pradhan, D. 2011. High temperature-induced oxidative stress in Lens culinaris, role of antioxidants and amelioration of stress by chemical pre-treatments. J. Plant Interact. 6:4352.
Chan-Schaminet, K.Y. , Baniwal, S.K. , Bublak, D. , Nover, L. , Scharf, K.D. 2009. Specific interaction between tomato HsfA1 and HsfA2 creates hetero-oligomeric superactivator complexes for synergistic activation of heat stress gene expression. J. Biol. Chem. 284:2084820857.
Chen, P. , Yu, S. , Zhan, Y. , Kang, X.L. 2006. Effects of jasmonate acid on thermotolerance of grape seedlings. J. Shihezi Univ. Nat. Sci. 24:8791.
Chhabra, M.L. , Dhawan, A. , Sangwan, N. , Dhawan, K. , Singh, D. 2009. Phytohormones induced amelioration of high temperature stress in Brassica juncea (L.) Czern & Coss. Proceedings of 16th Australian Research Assembly on Brassicas, September 1014, Ballarat, Australia.
Cossani, C.M. , Reynolds, M.P. 2012. Physiological traits for improving heat tolerance in wheat. Plant Physiol. 160:17101718.
Das, K. , Roychoudhury, A. 2014. Reactive oxygen species (ROS) and response of antioxidants as ROS-scavengers during environmental stress in plants. Front. Environ. Sci. 2:10.
Dawson, I.A. , Wardlaw, I.F. 1989. The tolerance of wheat to high temperatures during reproductive growth III. Booting to anthesis. Aust. J. Agric. Res. 40:965980.
Driedonks, N. , Xu, J. , Peters, J.L. , Park, S. , Rieu, I. 2015. Multi-level interactions between heat shock factors, heat shock proteins, and the redox system regulate acclimation to heat. Front. Plant Sci. 6:999.
Duan, J. , Cai, W. 2012. OsLEA32, an abiotic stress induced gene of rice plays a key role in salt and drought tolerance. PLoS One 7:e45117.
71 Endo, M. , Tsuchiya, T. , Hamada, K. , Kawamura, S. , Yano, K. , Ohshima, M. , Higashitani, A. , Watanabe, M. , Kawagishi-Kobayashi, M. 2009. High temperatures cause male sterility in rice plants with transcriptional alterations during pollen development. Plant Cell Physiol. 50:19111922.
Evrard, A. , Kumar, M. , Lecourieux, D. , Lucks, J. , von Koskull-Dring, P. , Hirt, H. 2013. Regulation of the heat stress response in Arabidopsis by MPK6-targeted phosphorylation of the heat stress factor HsfA2. Peer J. 1:e59.
Farooq, M. , Bramley, H. , Palta, J.A. , Siddique, K.H.M. 2011. Heat stress in wheat during reproductive and grain-filling phases. Crit. Rev. Plant Sci. 30:491507.
Fooland, M.R. 2005. Breeding for abiotic stress tolerances in tomato. In: Ashraf, M. , Harris, P.J.C. , eds. Abiotic Stresses: Plant Resistance through Breeding and Molecular Approaches. New York, NY: The Haworth Press, pp. 613684.
Foyer, C.H. 2015. Redox homeostasis: Opening up ascorbate transport. Nat. Plants 1:1401.
Foyer, C.H. , Noctor, G. 2012. Managing the cellular redox hub in photosynthetic organisms. Plant Cell Environ. 35:199201.
Frank, G. , Pressman, E. , Ophir, R. , Althan, L. , Shaked, R. , Freedman, M. , Shen, S. , Firon, N. 2009. Transcriptional profiling of maturing tomato (Solanum lycopersicum L) microspores reveals the involvement of heat shock proteins, ROS scavengers, hormones, and sugars in the heat stress response. J. Exp. Bot. 60:38913908.
Ginzberg, I. , Barel, G. , Ophir, R. , Tzin, E. , Tanami, Z. , Muddarangappa, T. , de Jong, W. , Fogelman, E. 2011. Transcriptomic profiling of heatstress response in potato periderm. J. Exp. Bot. 60:44114421.

Goyal, M. , Asthir, B. 2010. Polyamine catabolism influences antioxidative defense mechanism in shoots and roots of five wheat genotypes under high temperature stress. Plant Growth Regul. 60:1325.

Hameed, A. , Goher, M. , Iqbal, N. 2012. Heat stress-induced cell death, changes in antioxidants, lipid peroxidation and protease activity in wheat leaves. J. Plant Growth Regul. 31:283291.

Hancock, R.D. , Morris, W.L. , Ducreux, L.J. , Morris, J.A. , Usman, M. , Verrall, S.R. , Fuller, J. , Simpson, C.G. , Zhang, R. , Hedley, P.E. 2014. Physiological, biochemical and molecular responses of the potato (Solanum tuberosum L.) plant to moderately elevated temperature. Plant Cell Environ. 37:439450.

Hartl, F.U. , Bracher, A. , Hayer-Hartl, M. 2011. Molecular chaperones in protein folding and proteostasis. Nature 475:324332.

Hasanuzzaman, M. , Alam, M.M. , Rahman, A. , Hasanuzzaman, M. , Nahar, K. , Fujita, M. 2014. Exogenous proline and glycine betaine mediated upregulation of antioxidant defense and glyoxalase systems provides better protection against salt-induced oxidative stress in two rice (Oryza sativa L.) varieties. BioMed. Res Int. 2014:757219.

Hasanuzzaman, M. , Hossain, M.A. , Teixeira da Silva, J.A. , Fujita, M . 2012a. Plant responses and tolerance to abiotic oxidative stress: Antioxidant defense is a key factor. In: Bandi, V. , Shanker, A.K. , Shanker, C. , Mandapaka, M. , eds. Crop Stress and Its Management: Perspectives and Strategies. Berlin: Springer, pp. 261316.

Hincha, D.K. , Thalhammer, A. 2012. LEA proteins: IDPs with versatile functions in cellular dehydration tolerance. Biochem. Soc. Trans. 40:10001003.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Jagadish, S.V.K. , Muthurajan, R. , Oane, R. , Wheeler, T.R. , Heuer, S. , Bennett, J. , Craufurd, P.Q. 2010. Physiological and proteomic approaches to address heat tolerance during anthesis in rice (Oryza sativa L.). J. Exp. Bot. 61:143156.

Jiang-lin, L. , Hong-yu, Z. , Xue-lian, S. , Ping-an, Z. , Ying-jin, H. 2011. Identification for heat tolerance in backcross recombinant lines and screening of backcross introgression lines with heat tolerance at milky stage in rice. Rice Sci. 18:279286.

Kaushal, N. , Bhandari, K. , Siddique, K.H.M. , Nayyar, H. 2016. Food crops face rising temperatures: An overview of responses, adaptive mechanisms, and approaches to improve heat tolerance. Cogent Food Agric. 2:1134380.

Kaushal, N. , Gupta, K. , Bhandhari, K. , Kumar, S. , Thakur, P. , Nayyar, H. 2011. Proline induces heat tolerance in chickpea (Cicer arietinum L.) plants by protecting vital enzymes of carbon and antioxidative metabolism. Physiol. Mol. Biol. Plants 17:203213.

Kobayashi, A. , Sonoda, J. , Sugimoto, K. , Kondo, M. , Iwasawa, N. , Hayashi, T. , Tomita, K. , Yano, M. , Shimizu, T. 2013. Detection and verification of QTLs associated with heat-induced quality decline of rice (Oryza sativa L.) using recombinant inbred lines and near-isogenic lines. Breed. Sci. 63:339346.

Kocsy, G. , Tari, I. , Vankova, R. , Zechmanne, B. , Gulyas, Z. , Poor, P. 2013. Redox control of plant growth and development. Plant Sci. 211:7791.

Kotak, S. , Larkindale, J. , Lee, U. , von Koskull-Doring, P. , Vierling, E. , Scharf, K.D. 2007. Complexity of the heat stress response in plants. Curr. Opin. Plant Biol. 10:310316.

Kumar, S. , Gupta, D. , Nayyar, H. 2012c. Comparative response of maize and rice genotypes to heat stress: Status of oxidative stress and antioxidants. Acta Physiol. Planta. 34:7586.

Kumar, M. , Sirhindi, G. , Bhardwaj, R. , Kumar, S. , Jain, G. 2010. Effect of exogenous H2O2 on antioxidant enzymes of Brassica juncea L. seedlings in relation to 24-epibrassinolide under chilling stress. Indian J. Biochem. Biophys. 47:378382.

Lee, J.H. , Hubel, A. , Schoffl, F. 1995. Derepression of the activity of genetically engineered heat shock factor causes constitutive synthesis of heat shock proteins and increased thermotolerance in transgenic Arabidopsis. Plant J. 8:603612.

Lei, D. , Tan, L. , Liu, F. , Chen, L. , Sun, C. 2013. Identification of heat-sensitive QTL derived from common wild rice (Oryza rufipogon Griff.). Plant Sci. 201202:121127.

Liu, H.C. , Charng, Y.Y. 2013. Common and distinct functions of Arabidopsis class A1 and A2 heat shock factors in diverse abiotic stress responses and development. Plant Physiol. 163:276290.

Malik, M.K. , Slovin, J.P. , Hwang, C.H. , Zimmerman, J.L. 1999. Modified expression of a carrot small heat shock protein gene, Hsp17.7, results in increased or decreased thermotolerance. Plant J. 20:8999.

Mangelsen, E. , Kilian, J. , Harter, K. , Jansson, C. , Wanke, D. , Sundberg, E. 2011. Transcriptome analysis of high-temperature stress in developing barley caryopses: Early stress responses and effects on storage compound biosynthesis. Mol. Plant. 4:97115.

Matsui, T. , Omasa, K. , Horie, T. 2000. High temperature at flowering inhibits swelling of pollen grains, a driving force for thecae dehiscence in rice. Plant Prod. Sci. 3: 430434.

Matsukura, S. , Mizoi, J. , Yoshida, T. , Todaka, D. , Ito, Y. , Maruyama, K. 2010. Comprehensive analysis of rice DREB2-type genes 72that encode transcription factors involved in the expression of abiotic stress-responsive genes. Mol. Genet. Genom. 283:185196.

Mirzaei, M. , Pascovici, D. , Atwell, B.J. , Haynes, P.A. 2012. Differential regulation of aquaporins, small GTPases and V-ATPases proteins in rice leaves subjected to drought stress and recovery. Proteomics 12:864877.

Paliwal, R. , Rder, M.S. , Kumar, U. , Srivastava, J. , Joshi, A.K. 2012. QTL mapping of terminal heat tolerance in hexaploid wheat (T. aestivum L.). Theor. Appl. Genet. 125:561575.

Pathak, M.R. , Teixeira da Silva, J.A. , Wani, S.H. 2014. Polyamines in response to abiotic stress tolerance through transgenic approaches. GM Crops Food 5:8796.

Prasad, P.V.V. , Boote, K.J. , Allen, L.H.J.R. 2006a. Adverse high temperature effects on pollen viability, seed-set, seed yield and harvest index of grain-sorghum [Sorghum bicolor (L.) Moench] are more severe at elevated carbon dioxide due to higher tissue temperature. Agric. For. Meteor. 139:237251.

Prasad, P.V.V. , Boote, K.J. , Allen, L.H.J.R. , Sheehy, J.E. , Thomas, J.M.G. 2006b. Species, ecotype and cultivar differences in spikelet fertility and harvest index of rice in response to high temperature stress. Field Crops Res. 95:398411.

Qi, Y. , Wang, H. , Zou, Y. , Liu, C. , Liu, Y. , Wang, Y. 2011. Over-expression of mitochondrial heat shock protein 70 suppresses programmed cell death in rice. FEBS Lett. 585:231239.

Qin, D. , Wu, H. , Peng, H. , Yao, Y. , Ni, Z. , Li, Z. , Zhou, C. , Sun, Q. 2008. Heat stress-responsive transcriptome analysis in heat susceptible and tolerant wheat (Triticum aestivum L) by using Wheat Genome Array. BMC Genom. 9:432.

Ramakrishna, A. , Ravishankar, G.A. 2011. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal. Behav. 6:17201731.

Ramakrishna, A. , Ravishankar, G.A. 2013. Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Ramakrishna, A., Ravishankar, G.A., eds. Climate Change and Plant Abiotic Stress Tolerance, Wiley-VCH Verlag GmbH & Co. KGaA, pp. 705 705.

Rani, T. , Yadav, R.C. , Yadav, N.R. , Rani, A. , Singh, D. 2013. A genetic transformation in oilseed brassicasA review. Indian J. Agric. Sci. 83:367373.

Ristic, Z. , Momilovi, I. , Bukovnik, U. , Prasad, P. , Fu, J. , DeRidder, B.P. 2009. Rubisco activase and wheat productivity under heat-stress conditions. J. Exp. Bot. 60:40034014.

Saini, H.S. , Aspinall, D. 1982. Abnormal sporogenesis in wheat (Triticum aestivum L.) induced by short periods of high-temperature. Ann. Bot. 49:835846.

Saini, H.S. , Sedgley, M. , Aspinall, D. 1984. Developmental anatomy in wheat of male-sterility induced by heat-stress, water deficit or abscisic acid. Aust. J. Plant Physiol. 11:243253.
Sairam, R.K. , Tyagi, A. 2004. Physiology and molecular biology of salinity stress tolerance in plants. Curr. Sci. 86:407421.
Sakata, T. , Takahashi, H. , Nishiyama, I. , Higashitani, A. 2000. Effects of high temperature on the development of pollen mother cells and microspores in barley Hordeum vulgare L. J. Plant Res. 113:395402.
Snchez-Rodrguez, E. , Moreno, D.A. , Ferreres, F. , Rubio-Wilhelmi, M.M. , Ruiz, J.M. 2011. Differential responses of five cherry tomato varieties to water stress: Changes on phenolic metabolites and related enzymes. Phytochemistry 72:723729.
Sanmiya, K. , Suzuki, K. , Egawa, Y. , Shono, M. 2004. Mitochondrial small heat-shock protein enhances thermotolerance in tobacco plants. FEBS Lett. 557:265268.
Sato, H. , Mizoi, J. , Tanaka, H. 2014. Arabidopsis DPB3-1, a DREB2A interactor, specifically enhances heat stress-induced gene expression by forming a heat stress-specific transcriptional complex with NF-Y subunits. Plant Cell 26:49544973.
Savicka, M. , Skute, N. 2010. Effects of high temperature on malondialdehyde content, superoxide production and growth changes in wheat seedlings (Triticum aestivum L.). Ekologija 56:2633.
Sung, D.Y. , Kaplan, F. , Lee, K.J. , Guy, C.L. 2003. Acquired tolerance to temperature extremes. Trends Plant Sci. 8:179187.
Suzuki, N. , Koussevitzky, S. , Mittler, R. , Miller, G. 2012. ROS and redox signalling in the response of plants to abiotic stress. Plant Cell Environ. 35:259270.
Suzuki, N. , Mittler, R. 2006. Reactive oxygen species and temperature stresses: A delicate balance between signaling and destruction. Physiol. Plant. 126:4551.
Tikhomirova, E.V. 1985. Changes of nitrogen metabolism in millet at elevated temperatures. Field Crops Res. 11:259264.
Timperio, A.M. , Egidi, M.G. , Zolla, L. 2008. Proteomics applied on plant abiotic stresses: Role of heat shock proteins (HSP). J. Proteomics 71:391411.
Tolleter, D. , Hincha, D.K. , Macherel, D. 2010. A mitochondrial late embryogenesis abundant protein stabilizes model membranes in the dry state. Biochim. Biophys. Acta 1798:19261933.
Tripathy, B.C. , Oelmller, R. 2012. Reactive oxygen species generation and signaling in plants. Plant Signal. Behav. 7:16211633.
Wang, B.F. , Wang, Y. , Zhang, D . 2008 Verification of the resistance of a LEA gene from Tamarix expression in Saccharomyces to abiotic stresses. J. For. Res. 19:5862.
Wang, W. , Vinocur, B. , Shoseyov, O. , Altman, A. 2004. Role of plant heat-shock proteins and molecular chaperones in the abiotic stress response. Trends Plant Sci. 9:244252.
Wise, R. , Olson, A. , Schrader, S. , Sharkey, T. 2004. Electron transport is the functional limitation of photosynthesis in field-grown pima cotton plants at high temperature. Plant Cell Environ. 27:717724.
Xu, S. , Li, J. , Zhang, X. , Wei, H. , Cui, L. 2006. Effects of heat acclimation pre-treatment on changes of membrane lipid peroxidation, antioxidant metabolites, and ultrastructure of chloroplasts in two cool-season turf grass species under heat stress. Environ. Exp. Bot. 56:274285.
Ye, C. , Argayoso, M.A. , Redoa, E.D. , Sierra, S.N. , Laza, M.A. , Dilla, C.J. 2012. Mapping QTL for heat tolerance at flowering stage in rice using SNP markers. Plant Breed. 131:3341.

Profiles of Antioxidant Isoenzymes and Physiological Behavior of Tomato Exposed to NaCl Stress and Treated with Salicylic Acid

Amini F , Ehsanpour A.A. Soluble proteins, proline, carbohydrates and Na+/K+ changes in two tomato (Lycopersicon esculentum Mill.) cultivars under in vitro salt stress. Am. J. Biochem. Biotech. 2005; 1: 212216.
Apel K , Hirt H. Reactive oxygen species: Metabolism, oxidative stress, and signal transduction. Annu. Rev. Plant Physiol. Plant Mol. Biol. 2004; 55: 373399.
Askari H , Edqvist J , Hajheidari M , Kafi M , Salekdeh G.H. Effects of salinity levels on proteome of Suaeda aegyptiaca leaves. Proteomics 2006; 6: 25422554.
Bates L , Waldren R , Teare I. Rapid determination of free proline for water-stress studies. Plant Soil 1973; 39: 205207.
Beauchamp C , Fridovich I. Superoxide dismutase: Improved assays and an assay applicable to acrylamide gels. Anal. Biochem. 1971; 44: 276287.
Bennaceur M , Rahmoun C , Sdiri H , Medahi M , Selmi M. Effet du stress salin sur la germination, la croissance et la production de grains de bl. Scheresse 2001; 12: 167174.
Bradford M. A rapid and sensitive method for quantitation of microgram quantities of protein utilizing the principle of protein-dye-binding. Anal. Biochem. 1976; 72: 248254.
Brosch M , Overmyer K , Wrzaczek M , Kangasjrvi J, Kangasjrvi S. Chapter 5: Stress signaling III: Reactive oxygen species (ROS). In: Pareek SA , Sopory SK , Bohnert HJ and Govindjee HJ (eds.). Abiotic Stress Adaptation in Plants: Physiological, Molecular and Genomic Foundation, 2010; pp. 91 91.
Bybordi A. Effect of ascorbic acid and silicium on photosynthesis, antioxidant enzyme activity, and fatty acid contents in canola exposure to salt stress. J. Integr. Agric. 2012; 11: 16101620.
Bybordi A. Interactive effects of silicon and potassium nitrate in improving salt tolerance of wheat. J. Integr. Agric. 2014; 13: 18891899.
Chakraborty U , Tongden C. Evaluation of heat acclimation and salicylic acid treatments as potent inducers of thermotolerance in Cicer arietinum L. Curr. Sci. 2005; 89: 384389.
Davis BJ . Disc electrophoresis. II. Method and application to human serum proteins. Ann. N Y Acad. Sci. 1964; 121: 404427.
Del Rio LA , Corpas FJ , Sandalio LM , Palma JM , Gomez M , Barroso JB . Reactive oxygen species, antioxidant systems and nitric oxide in peroxisomes. J. Exp. Bot. 2002; 53: 12551272.
El-Khallal SM , Hathout TA , Ashour AEA , Kerrit A.A. Brassinolide and salicylic acid induced growth, biochemical activities and productivity of maize plants grown under salt stress. Res. J. Agric. Biol. Sci. 2009; 5: 380390.
El Sayed Hameda EA , Baziad Salih AM , Basaba Reem AAS . Alleviation of adverse effects of salinity stress on tomato (Solanum lycopersicum L.) plants by exogenous application of ascorbic acid. Eur. J. Acad. Essays 2015; 2: 2333.
El-Tayeb M. Response of barley grains to the interactive effect of salinity and salicylic acid. Plant Growth Regul. 2005; 45: 215224.
Fahad S , Bano A. Effect of salicylic acid on physiological and biochemical characterization of maize grown in saline area. Pak. J. Bot. 2012; 44: 14331438.
FAO . (Food and Agricultural Organization). Land and plant nutrition management service. 2008. www.fao.org/ag/agl/agll/spush.
Ganesan V , Thomas G. Salicylic acid response in rice: Influence of salicylic acid on H2O2 accumulation and oxidative stress. Plant Sci. 2001; 160: 10951106.

Grennan A.K. High impact abiotic stress in rice. An omic approach. Plant Physiol. 2006; 140: 11391141.
Gunes A , Inal A , Alpaslan M , Eraslan F , Bagci EG , Cicek N. Salicylic acid induced changes on some physiological parameters symptomatic for oxidative stress and mineral nutrition in maize (Zea mays L.) grown under salinity. J. Plant Physiol. 2007; 16 4: 728736.
Hachicha M. Les sols sals et leur mise en valeur en Tunisie. Scheresse 2007; 18: 4550.
Hsu SY , Hsu YT , Kao C.H. The effect of polyethylene glycol on proline accumulation in rice leaves. Biol. Plant 2003; 46: 7378.
Hua L. Dissection of salicylic acid-mediated defense signaling networks. Plant Signal Behav. 2009; 4(8): 713717.
Kafi M , Nabati J , Masoumi A , Mehrgerd M.Z. Effect of salinity and silicon application on oxidative damage of sorghum [Sorghum bicolor (L.) moench.]. Pak. J. Bot. 2011; 43: 24572462.
Kaur H , Mukherjee S , Baluska F , Bhatla S.C. Regulatory roles of serotonin and melatonin in abiotic stress tolerance in plants. Plant Signal. Behav. 2015; 10(11): e1049788. doi:10.1080/15592324.2015.1049788.
Khan MIR , Asgher M , Khan N.A. Alleviation of salt-induced photosynthesis and growth inhibition by salicylic acid involves glycinebetaine and ethylene in mungbean (Vigna radiata L.). Plant Physiol. Biochem. 2014; 80: 6774.
80 Krantev A , Yordanova R , Janda T , Szalai G , Popova L. Treatment with salicylic acid decreases the effect of cadmium on photosynthesis in maize plants. J. Plant Physiol. 2008; 165: 920931.
Kumar P , Jyothi LN , Mani V.P. Interactive effects of salicylic acid and phytohormones on photosynthesis and grain yield of soybean (Glycine max L. Merrill). Plant Physiol. Plant Mol. Biol. 2000; 6: 179186.
Lakzayi M , Sabbagh E , Rigi K , Keshtehgar A. Effect of salicylic acid on activities of antioxidant enzymes, flowering and fruit yield and the role on reduce of drought stress. Int. J. Farm. Allied Sci. 2014; 3: 980987.
Li T , Hu Y , Du X , Tang H , Shen C , Wu J . Salicylic acid alleviates the adverse effects of salt stress in Torreya grandis cv. Merrillii seedlings by activating photosynthesis and enhancing antioxidant systems. PLoS One 2014; 9(10): e109492. doi:10.1371/journal.pone.0109492.
Manaa A , Gharbi E , Mimouni H , Wasti S , Aschi-Smiti S , Lutts S , Ben Ahmed H. Simultaneous application of salicylic acid and calcium improves salt tolerance in two contrasting tomato (Solanum lycopersicum) cultivars. S. Afr. J. Bot. 2014; 95: 3239.
Martnez JP , Kinet JM , Bajji M , Lutts S. NaCl alleviates polyethylene glycol-induced water stress in the halophyte species Atriplex halimus L. J. Exp. Bot. 2005; 6: 24212431.
Mezni M , Albouchi A , Bizid E , Hamza M. Effet de la salinit des eaux dirrigation sur la nutrition minrale chez trois varits de luzerne prenne (Medicago sativa L.). Agronomie 2002; 22: 283291.
Mimouni H , Wasti S , Manaa A , Chalh A , Vandoorne B , Lutts S , Ben Ahmed H. Does salicylic acid (SA) improve tolerance to salt stress in plants? A study of SA effects on tomato plant growth, water dynamics, photosynthesis, and biochemical parameters. Omics 2016; 20: 180190.
Molassiotis A , Sotiropoulos T , Tanou G , Diamantidis G , Therios I. Boron induced oxidative damage and antioxidant and nucleolytic responses in shoot tips culture of the apple rootstock EM9 (Malus domestica Borkh). Environ. Exp. Bot. 2006; 56: 5462.
Munns R , James RA , Lauchli A. Approaches to increasing the salt tolerance of wheat and other cereals. J. Exp. Bot. 2006; 57: 10251043.
Munns R , Tester M. Mechanisms of salinity tolerance. Ann. Rev. Plant Biol. 2008; 59: 651681.
Navari-Izzo F , Quartacci MF , Pinzino C , Dalla vecchia F , Sgherri CLM . Thylakoid-bound and stromal antioxidative enzymes in wheat treated with excess copper. Physiol. Plant. 1998; 104: 630638.
Ndhala AR , Moyo M , Staden J. Natural antioxidants: Fascinating or mythical biomolecules? Molecules 2010; 15: 69056930.
Pareek A , Singla SL , Grover A. Salt responsive proteins/genes in crop plants. In: Jaiwal PK , Singh RP , Gulati A (eds.). Strategies for Improving Salt Tolerance in Higher Plants. Science Publishers, USA, 1997; pp. 365 365.
Sairam RK , Rao KV , Srivastava G.C. Differential response of wheat genotypes to long term salinity stress in relation to oxidative stress, antioxidant activity and osmolyte concentration. Plant Sci. 2002; 163: 10371046.
Sairam RK , Srivastava GC , Agarwal S , Meena R.C. Differences in antioxidant activity in response to salinity stress in tolerant and susceptible wheat genotypes. Biol. Plant. 2005; 49: 8591.
Sakhabutdinova AR , Fatkhutdinova DR , Bezrukova MV , Shakirova F.M. Salicylic acid prevents the damaging action of stress factors on wheat plants. Bulg. J. Plant Physiol. 2003; 314319.
Schutzendubel A , Polle A. Plant responses to abiotic stresses: heavy metal-induced oxidative stress and protection by mycorrhization. J. Exp. Bot. 2002; 53: 13511365.
Szalai G , Krantev A , Yordanova R , Popova LP , Janda T. Influence of salicylic acid on phytochelatin synthesis in Zea mays during Cd stress. Turk. J. Bot. 2013; 37: 708714.
Tari I , Csiszar J , Szalai G , Horvath F , Pecsvaradi A , Kiss G , Szepesi A , Szabo M , Erdei L. Acclimation of tomato plants to salinity stress after a salicylic acid pre-treatment. Acta Biol. Szeged 2002; 46: 5556.
Tasgin E , Atici O , Nalbantoglu B. Effects of salicylic acid and cold on freezing tolerance in winter wheat leaves. Plant Growth Regul. 2003; 41: 231236.
Tewari RK , Kim S , Hahn EJ , Paek K.Y. Involvement of nitric oxide-induced NADPH oxidase in adventitious rootgrowth and antioxidant defense in Panax ginseng. Plant Biotechnol. Rep. 2008; 2: 113122.
Trinchant JC , Boscari A , Spennato G , Van de Sype G , Le Rudulier D. Proline betaine accumulation and metabolism in alfalfa plants under sodium chloride stress. Exploring its compartmentalization in nodules. Plant Physiol. 2004; 135: 15831594.
Vallejos C.E. Enzyme activity staining. In: Tanksley SD , Orton TJ (eds.). Isozymes in Plant Genetics and Breeding. Part A. Elsevier, Amsterdam, The Netherlands, 1983; pp. 469516.
Wasti S , Manaa A , Mimouni H , Nasairi A , Medyouni I , Gharbi E , Gautier H , Ben Ahmed H. Exogenous application of calcium silicate improves salt tolerance in two contrasting tomato (Solanum lycopersicum) cultivars. J. Plant Nutr. 2017; 4: 673684.
Wasti S , Mimouni H , Smiti S , Zid E , Ben Ahmed H. Enhanced salt tolerance of tomatoes by exogenous salicylic acid applied through rooting medium. Omics 2012; 16: 200207.
Wei W , Li QT, Chu YN , Reiter RJ , Yu XM , Zhu DH , Zhang WK , et al. Melatonin enhances plant growth and abiotic stress tolerance in soybean plants. J. Exp. Bot. 2015; 66(3): 695707.
Wolf B. A comprehensive system of leaf analyses and its use for diagnosing crop nutrient status. Commun. Soil Sci. Plant Anal. 1982; 13: 10351059.
Zhou ZS , Guo K , Elbaz AA , Yang Z.M. Salicylic acid alleviates mercury toxicity by preventing oxidative stress in roots of Medicago sativa. Environ. Exp. Bot. 2009; 65: 2734.

Toxicity of Heavy Metal and Its Mitigation Strategies Through Application of Nutrients, Hormones, and Metabolites

Adamiec E , Helios-Rybicka E. Distribution of pollutants in the Odra river system part IV. Heavy metal distribution in water of the upper and middle Odra River, 19982000. Pol. J. Environ. Stud. 2002;11:669673.

Agency for Toxic Substances and Disease Registry . Toxicological profile for chromium. US Public Health Service, Washington, DC, 1989 (ATSFDR/TP 88/10).

Ahmad P , Abdel Latef AA , AbdAllah EF , Hashem A , Sarwat M , Anjum NA , Gucel S. Calcium and potassium supplementation enhanced growth, osmolyte secondary metabolite production, and enzymatic antioxidant machinery in cadmium-exposed chickpea (Cicer arietinum L.). Front. Plant Sci. 2016;7:513.

Ahmad P , Alyemeni MN , Wijaya L , Alam P , Ahanger MA , Alamri S.A. Jasmonic acid alleviates negative impacts of cadmium stress by modifying osmolytes and antioxidants in faba bean (Vicia faba L.). Arch. Agron. Soil Sci. 2017;1:111.

Al Saleh I , Shinwari N. Report on the levels of cadmium, lead and mercury in imported rice grain samples. Biol. Trace Elem. Res. 2001;83:9196.

Alcantara E , Romera FJ , Canete M , De La Guardia MD. Effects of heavy metals on both induction and function of root Fe(III) reductase in Fe-deficient cucumber (Cucumis sativus L.) plants. J. Exp. Bot. 1994;45:18931898.

Al-Hakimi A.M.A. Modification of cadmium toxicity in pea seedlings by kinetin. Plant Soil Environ. 2007;53:129135.

Al-Hiyaly SA , McNeilly T , Bradshaw A.D. The effect of zinc concentration from electricity pylons-evolution in replicated situation. New Phytol. 1988;110:571580.

Angino EE , Magnuson LM , Waugh TC , Galle OK , Bredfeldt J. Arsenic in detergents: Possible danger and pollution hazard. Science 1970;168:389392.

Anjum NA , Ahmad I , Mohmood I , Pacheco M , Duarte AC , Pereira E , Umar S , Ahmad A , Khan NA , Iqbal M , Prasad M.N.V. Modulation of glutathione and its related enzymes in plants responses to toxic metals and metalloidsA review. Environ. Exp. Bot. 2012;75:307324.

Anjum NA , Ibrahim MA , Armando CD , Eduarda P , Ahmad I , Iqbal M. Glutathione and proline can coordinately make plants withstand the joint attack of metal(loid) and salinity stresses. Front. Plant Sci. 2014;5:662.

92 Anjum NA , Umar S , Chan M.T. Ascorbate-Glutathione Pathway and Stress Tolerance in Plants. Springer, Dordrecht, 2010.

Anjum SA , Xie XY , Farooq M , Wang LC , Xue LI , Shahbaz M , Salhab J. Effect of exogenous methyl jasmonate on growth, gas exchange and chlorophyll contents of soybean subjected to drought. Afr. J. Biotechnol. 2011;24:96479656.

Anuradha S , Rao S.S.R. Effect of 24-epibrassinolide on the growth and antioxidant enzyme activities in radish seedlings under lead toxicity. Indian J. Plant Physiol. 2007a;12:396400.

Anuradha S , Rao S.S.R. The effect of brassinosteroids on radish (Raphanus sativus L.) seedlings growing under cadmium stress. Plant Soil Environ. 2007b;5:465472.

Arora A , Sairam RK , Srivastava G.C. Oxidative stress and antioxidative system in plants. Curr. Sci. 2002;82:12271338.

Astolfi S , Zuchi S , Passera C. Role of sulphur availability on cadmium-induced changes of nitrogen and sulphur metabolism in maize (Zea mays L.) leaves. J. Plant Physiol. 2004;61:795802.

Bajguz A. Blockade of heavy metals accumulation in Chlorella vulgaris cells by 24-epibrassinolide. Plant Physiol. Biochem. 2000;38:797801.

Bajguz A. Brassinosteroids and lead as stimulators of phytochelatins synthesis in Chlorella vulgaris. J. Plant Physiol. 2002;159:321324.

Bakkaus E , Gouget B , Gallien JP , Khodja H , Carrot H , Morel JL , Collins R. Concentration and distribution of cobalt in higher plants: The use of micro-PIXE spectroscopy. Nucl. Instr. Methods B 2005;231:350356.

Barciszewski J , Siboska G , Rattan SIS , Clark BFC . Occurrence, biosynthesis and properties of kinetin (N6-furfurylade- nine). Plant Growth Regul. 2000;32:257265.

Barghiani C , Gloffre D , Bargali R. Mercury content in Pinus sp of the Mt. In: Etna Volcanic Area, in Heavy Metals in the Environment, 2. Lindberg JE , Hutchinson TC (Eds.). New Orleans, 1987; 51.

Bashir H , Ibrahim MM , Bagheri R , Ahmad J , Arif IA , Baig MA , Qureshi M.I. Influence of sulfur and cadmium on antioxidants, phytochelatins and growth in Indian mustard. AoB PLANTS 2015;7.

Bashri G , Prasad S.M. Indole acetic acid modulates changes in growth, chlorophyll a fluorescence and antioxidant potential of Trigonella foenum graecum L. grown under cadmium stress. Acta Physiol. Plant. 2015;37:49.

Battke F , Ernst D , Halbach S. Ascorbate promotes emission of mercury vapour from plants. Plant Cell Environ. 2005;28:14871495.

Becker M , Asch F. Iron toxicity in riceConditions and management concepts. J. Plant Nutr. Soil Sci. 2005;168:558.

Bhardwaj R , Arora N , Sharma P , Arora H.K. Effects of 28- homobrassinolide on seedling growth, lipid peroxidation and antioxidative enzyme activities under nickel stress in seedlings of Zea mays L. Asian J. Plant Sci. 2007;6:765772.

Boonyapookana B , Upatham ES , Kruatrachue M , Pokethitiyook P , Singhakaew S. Phytoaccumulation and phytotoxicity of cadmium and chromium in duckweed Wolffia globosa. Int. J. Phytoremed. 2002;4:87100.

Bradford W.I. Urban storm water pollutant loadings a statistical summary through. JWPCF 1997;49:610613.

Burritt D.J. Proline and the cryopreservation of plant tissues: Functions and practical applications. In: Current Frontiers in Cryopreservation. Katkov I (Eds.), InTech, Rijeka, Croatia, 2012; 415426.

Cai Y , Aoshima K , Katoh T , Teranishi H , Kasuya M. Renal tubular dysfunction in male inhabitants of a cadmium-polluted area in Toyama, Japan An eleven year follow-up study. J. Epidemiol. 2001;18:180189.

Cairns NG , Pasternak M , Wachter A , Cobbett CS , Meyer A.J. Maturation of Arabidopsis seeds is dependent on glutathione biosynthesis within the embryo. Plant Physiol. 2006;141:446455.

Cakmak I , Marshner H. Effect of zinc nutritional status on superoxide radical and hydrogen peroxide scavenging enzymes in bean leaves. In: Plant NutritionFrom Genetic Engineering Field Practice. Barrow NJ (Eds.). Kluwer, the Netherlands, 1993;133137.

Cao S , Zheng Y , Wang K , Jin P , Rui H. Methyl jasmonate reduces chilling injury and enhances antioxidant enzyme activity in postharvest loquat fruit. Food Chem. 2009;115:14581463.

Cargnelutti D , Tabaldi LA , Spanevello RM , Jucoski GO , Battisti V , Redin M , Linares CEB , Dressler VL , Flores MM , Nicoloso FT , Morsch VM , Schetinger M.R.C. Mercury toxicity induces oxidative stress in growing cucumber seedlings. Chemosphere 2006;65:9991106.

Chaffei C , Gouia H , Debouba M , Ghorbel M.H. Differential toxicological response to cadmium stress of bean seedlings grown with NO3 or NH4 + as nitrogen source. Int. J. Bot. 2008;4:1423.

Chandramouli K , Unciuleac MC , Naik S , Dean DR , Huynh BH , Johnson MK . Formation and properties of [4Fe__4S] clusters on the IscU scaffold protein. Biochemistry 2007;46:68046811.

Chatterjee J , Chatterjee C. Phytotoxicity of cobalt, chromium and copper in cauliflower. Environ. Pollut. 2000;109:6974.

Clarimont KB , Hagar WG , Davis E.A. Manganese toxicity to chlorophyll synthesis in tobacco callus. Plant Physiol. 1986;80:291293.

Clijsters H , Van Assche F. Inhibition of photosynthesis by heavy metals. Photosynth. Res. 1985;7:3140.

Climino G , Ziino M. Heavy metal pollution part VII emissions from Etna volcanic. Geophys. Res. Lett. 1983;10:3138.

Das HK , Mitra AK , Sengupta PK , Hossain A , Islam F , Rabbani G.H. Arsenic concentrations in rice, vegetables, and fish in Bangladesh: A preliminary study. Environ. Int. 2004;30:383387.

Das P , Samantaray S , Rout G.R. Studies on cadmium toxicity in plants: A review. Environ. Pollut. 1997;98:2936.

de Dorlodot S , Lutts S , Bertin P. Effects of ferrous iron toxicity on the growth and mineral composition of an inter specific rice. J. Plant Nutr. 2005;28:120.

De Filippis LF , Ziegler H. Effect of sublethal concentrations of zinc, cadmium and mercury on the photosynthetic carbon reduction cycle of Euglena. J. Plant Physiol. 1993;142:167172.

Demirevska-Kepova K , Simova-Stoilova L , Stoyanova Z , Holzer R , Feller U. Biochemical changes in barley plants after excessive supply of copper and manganese. Environ Exp Bot. 2004;52:253266.

DeVolder PS , Brown SL , Hesterberg D , Pandya K. Metal bioavailability an d speciation in a wetland tailings repository amended with biosolids compost, wood ash, and sulphate. J. Environ. Qual. 2003;32:851864.

Dodd I.C. Hormonal interactions and stomatal responses. J. Plant Growth Regul. 2003;22:3246.

EFSA . Dietary exposure to inorganic arsenic in the European population. EFSA J. 2014;12:3597.

93 Ebbs SD , Kochian L.V. Toxicity of zinc and copper to Brassica species: Implications for phytoremediation. J. Environ. Qual. 1997;26:776781.

Edwards R , Dixon D. Plant glutathione transferases. Methods Enzymol. 2005;401:169186.

Edwards R , Dixon DP , Walbot V. Plant glutathione S-transferases: Enzymes with multiple functions in sickness and in health. Trends Plant Sci. 2000;5:193198.

Ei-Jaoual T , Cox D.A. Manganese toxicity in plants. J. Plant Nutr. 1998;21:353386.

Endo T , Haraguchi K , Sakata M. Mercury and selenium concentrations in internal organs of toothed whales and dolphins marketed for human consumption in Japan. Sci. Total Environ. 2002;300:1522.

Eshleman A , Siegel SM , Siegel B.Z. Is mercury from Hawaiian volcanoes a natural source of pollution? Nature 1971;223:471475.

Falter R , Scholer H.F. Determination of methyl-, ethyl-, phenyl and total mercury in Neckar River fish. Chemosphere 1994;29:13331338.

Farias JG , Bernardy K , Schwalbert R , del frari BK , Meharg A , Carey M , Marques ACR , Signes-pastor A , Sausen D , Schorr MRW , Tavares MS , Nicoloso FT . Effect of phosphorus on arsenic uptake and metabolism in rice cultivars differing in phosphorus use efficiency and response. An. Acad. Bras. Cinc. 2017;89:163174.

Farmer E.E. Plant biology: Jasmonate perception machines. Nature 2007;448:659660.

Foy CD , Weil RR , Coradetti C.A. Differential manganese tolerances of cotton genotypes in nutrient solution. J. Plant Nutr. 1995;18:685706.

Foyer CH , Noctor G. Redox homeostasis and antioxidant signaling: A metabolic interface between stress perception and physiological responses. Plant Cell 2005;17:18661875.

Gajewska E , Sklodowska M , Slaba M , Mazur J. Effect of nickel on antioxidative enzymes activities, proline and chlorophyll contents in wheat shoots. Biol. Planta. 2006;50:653659.

Gangwar S , Singh VP , Prasad SM , Maurya J.N. Modulation of manganese toxicity in Pisum sativum L. seedlings by kinetin. Sci. Hortic. 2010;126:467474.

Ghanta S , Datta R , Bhattacharyya D , Sinha R , Kumar D , Hazra S , Mazumdar AB , Chattopadhyay S. Multistep involvement of glutathione with salicylic acid and ethylene to combat environmental stress. J. Plant Physiol. 2014;171:940950.

Gill M. Heavy metal stress in plants: A review. Inter. J. Adv. Res. 2014;2:10431055.

Gill SS , Anjum, NA , Hasanuzzaman M , Gill R , Trivedi DK , Ahmad I , Pereira E , Tuteja, N. Glutathione and glutathione reductase: A boon in disguise for plant abiotic stress defense operations. Plant Physiol. Biochem. 2013;70:204212.

Gill SS , Gill R , Anjum N.A. Target osmoprotectants for abiotic stress tolerance in crop plantsGlycine betaine and proline. In: Plant Adaptation to Environmental Change: Significance of Amino Acids and Their Derivatives. Anjum NA , Gill SS , Gill R (Eds.). CAB International, Wallingford, CT, 2014;97108.

Gill SS , Tuteja N . Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol. Biochem. 2010;48:909930.

Gruenhage L , Jager HJ . Effect of heavy metals on growth and heavy metals content of Allium Porrum and Pisum sativum. Angew Bot. 1985;59:1128.

Gulson BL , Mizon KJ , Palmer JM , Patison N , Law AJ , Korsch MJ , Mahaffey KR , Donnelly J.B. Longitudinal study of daily intake and excretion of lead in newly born infants. Environ. Res. 2001;85:232245.

Guo J , Chen YZ , Li MS , Shi L , Yan XF . Does MYC2 really play a negative role in jasmonic acid-induced indolic glucosinolate biosynthesis in Arabidopsis thaliana? Russ. J. Plant Physiol. 2013;60:100107.

Guo J , Dai X , Xu W , Ma M. Over expressing GSHI and AsPCSI simultaneously increases the tolerance and accumulation of cadmium and arsenic in Arabidopsis thaliana. Chemosphere 2008;72:10201026.

GWRTAC . Remediation of metals-contaminated soils and groundwater. Tech. Rep. TE-97-01, GWRTAC, Pittsburgh, PA, 1997, GWRTAC-E Series.

Hamayun M , Shin JH , Khan SA , Ahmad B , Shin DH , Khan AL , Lee I.J. Exogenous gibberellic acid reprograms soybean to higher growth and salt stress tolerance. J. Agric. Food Chem. 2010;58: 72267232.

Han FX , Su Y , Monts DL , Waggoner AC , Plodinec J.M. Binding distribution, and plant uptake of mercury in a soil from Oak Ridge, Tennessee, USA. Sci. Total Environ. 2006;368:753768.

Handa B.K. Occurrence and distribution of chromium in natural waters of India. Adv. Environ. Sci. Technol. 1988;20:189214.

Hansell AL , Horwell CJ , Oppenheimer C. The health hazards of volcanoes and geothermal areas. Occup. Environ. Med. 2006;63:149156.

Hasan SA , Hayat S , Ahmad A. Brassinosteroids protect photosynthetic machinery against the cadmium induced oxidative stress in two tomato cultivars. Chemosphere 2011;84:14461451.

Hassan FM , Saleh MM , Salman J.M. A study of physicochemical parameters and nine heavy metals in the Euphrates River, Iraq. E-J Chem. 2010;7:685692.

Hawkes J.S. Heavy metals. J. Chem. Educ. 1997;74:13691374.

Hayat S , Ali B , Hassan SA , Ahmad A. Brassinosteroid enhanced the level of antioxidants under cadmium stress in Brassica juncea. Environ. Exp. Bot. 2007;60:3341.

Hayat S , Hasan SA , Hayat Q , Ahmad A. Brassinosteroids protect Lycopersicon esculentum from cadmium toxicity applied as shotgun approach. Protoplasma 2010;239:314.

Hegedus A , Erdei S , Horvath G. Comparative studies of H2O2 detoxifying enzymes in green and greening barley seedings under cadmium stress. Plant Sci. 2001;160:10851093.

Herawati N , Suzuki S , Hayashi K , Rivai IF , Koyoma H. Cadmium , copper and zinc levels in rice and soil of Japan, Indonesia and China by soil type. Bull. Environ. Contam. Toxicol. 2000;64:3339.

Hernandez L , Probst A , Probst JL , Ulrich E. Heavy metal distribution in some French forest soils: Evidence for atmospheric contamination. Sci. Total Environ. 2003;312:195219.
Hernandez LE , Carpena-Ruiz R , Garate A. Alterations in the mineral nutrition of pea seedlings exposed to cadmium. J. Plant Nutr. 1996;19:15811598.
Hirata K , Tsuji N , Miyamoto K. Biosynthetic regulation of phytochelatins, heavy metal-binding peptides. J. Biosci. Bioeng. 2005;100:593599.
Howarth JR , Domnguez-Sols JR , Guterrez-Alcal G , Wray JL , Romero LC , Gotor C. The serine acetyl transferase gene family in Arabidopsis thaliana and the regulation of its expression by cadmium. Plant Mol. Biol. 2003;51:589598.
94 Huang GY , Wang YS , Sun CC , Dong JD , Sun Z.X. The effect of multiple heavy metals on ascorbate, glutathione and related enzymes in two mangrove plant seedlings (Kandelia candel and Bruguiera gymnorrhiza). Oceanol. Hydrobiol. Stud. 2010;39:1125.
Huang YL , Yang S , Long GX , Zhao ZK , Li XF , Gu M.H. Manganese toxicity in sugarcane plantlets grown on acidic soils of Southern China. PLoS ONE 2016;11:e0148956.
Huggett DB , Steevens JA , Allgood JC , Lutken CB , Grace CA , Benson W.H. Mercury in sediment and fish from North Mississippi Lakes. Chemosphere 2001;42:923929.
Iqbal N , Umar S , Khan NA , Khan M.I.R. A new perspective of phytohormones in salinity tolerance: Regulation of proline metabolism. Environ. Exp. Bot. 2014;100:3442.
Irfan M , Ahmad A , Hayat S. Effect of cadmium on the growth and antioxidant enzymes in two varieties of Brassica juncea. Saudi J. Biol. Sci. 2014;21:125131.
Islam MS , Awal MA , Mostofa M , Begum F , Myenuddin M. Detection of arsenic in chickens and ducks. Int. J. Sci. Res. Manage. 2013;1:5662.
Izosimova A. Modelling the interaction between calcium and nickel in the soil-plant system. FAL Agric. Res., Special issue 2005;288:99.
Jain M , Khurana J.P. Transcript profiling reveals diverse roles of auxin-responsive genes during reproductive development and abiotic stress in rice. FEBS Lett. 2009;276:31483162.
Jean-Philippe S.R. Labb N , Franklin JA , Johnson A. Detection of mercury and other metals in mercury contaminated soils using mid-infrared spectroscopy. Proc. Int. Acad. Ecol. Environ. Sci. 2012;2:139149.
Jedrzejczak R. Determination of total mercury in foods of plant origin in Poland by cold vapour atomic absorption-spectrometry. Food Addit. Contam. 2002;19:9961002.
Jorhem L , Slorach S , Sundsstorm B , Ohlin B. Lead, cadmium, arsenic and mercury in meat, liver and kidney in Swedish pigs and cattle in 1984-88. Food Addit. Contam. 1991;8:201211.
Jorhem L , Sundsstorm B , Engman J. Cadmium and other metal in Swedish wheat and rye flours: Longitudinal study 19831997. J. AQAC Int. 2001;84:19841992.
Juwarkar AS , Shende G.B. Interaction of Cd-Pb effect on growth y ield and content of Cd, Pb in barley. Ind. J. Environ. Health 1986;28:235243.
Keramat B , Kalantari KM , Arvin M.J. Effects of methyl jasmonate in regulating cadmium induced oxidative stress in soybean plant (Glycine max L.). Afr. J. Microbiol. Res. 2009;31:240244.
Khan NA , Samiullah, Singh S , Nazar R. Activities of antioxidative enzymes, sulphur assimilation, photosynthetic activity and growth of wheat (Triticum aestivum) cultivars differing in yield potential under cadmium stress. J. Agron. Crop Sci. 2007;193:435444.
Khripach VA , Zhabinskii VN . De Groot AE . Brassinosteroids: A New Class of Plant Hormones. Academic Press, San Diego, 1999.
Kim KH , Kim S.H. Heavy metal contamination of agricultural soils in central regions of Korea. Water Air Soil Contam. 1999;111:109122.
Kitao M , Lei TT , Koike T. Effects of manganese in solution culture on the growth of five deciduous broad-leaved tree species with different successional characters from northern Japan. Photosynthetica 1997b;36:3140.
Kitao M , Lei TT , Koike T. Effects of manganese toxicity on photosynthesis of white birch (Betula platyphylla var. japonica) seedlings. Physiol. Plant. 1997a;101:249256.
Klein M , Burla B , Martinoia E. The multidrug resistance-associated proteins (MRP/ABCC) subfamily of ATP-binding cassette transporters in plants. FEBS Lett. 2006;580:11121122.
Kovcik J , Klejdus B , tork F , Hedbavny J , Backor M . Comparison of methyl jasmonate and cadmium effect on selected physiological parameters in Scenedesmus quadricauda (chlorophyta, chlorophyceae). J. Phycol. 2011;47:10441049.
Kristensen LJ , Taylor M.P. Fields and forests in flames: Lead and mercury emissions from wildfire pyrogenic activity. Environ. Health Perspect. 2012;120:a56a57.
Lacerda L.D. Global mercury emissions from gold and silver mining. Water Air Soil Pollut. 1997;97:209221.
Larsen EH , Andersen NL , Moller A , Petersen A , Mortensen GK , Petersen J. Monitoring the content and intake of trace elements from food in Denmark. Food Addit. Contam. 2002;19:3346.
Lee CW , Choi JM , Pak C.H. Micronutrient toxicity in seed geranium (Pelargonium x hortorum Bailey). J. Am. Soc. Hortic. Sci. 1996;121:7782.
Leigh RA , Jones R.G.W. A hypothesis relating critical potassium concentrations for growth to the distribution and functions of this ion in the plant-cell. New Phytol. 1984;97:113.
Lenntech Water Treatment and Air Purification . Water treatment. Lenntech, Rotterdamseweg, the Netherlands, 2004. excelwater.com/thp/filters/Water-Purification.htm).
Letham, DS , Goodwin PB , Higgins T.J.V. Phytohormones and related compounds: A comprehensive treatise. In: Phytohormones and the Development of Higher Plants, vol. 2. Letham DS , Goodwin PB , Higgins TJV (Eds.). Elsevier North-Holland Biomedical Press, Amsterdam, 1978.
Lewis S , Donkin ME , Depledge M.H. Hsp 70 expression in Enteromorpha intestinalis (Chlorophyta) exposed to environmental stressors. Aqua Toxicol. 2001;51:277291.
Li HF , Gray C , Mico C , Zhao FJ , McGrath S.P. Phytotoxicity and bioavailability of cobalt to plants in a range of soils. Chemosphere 2009;75:979986.
Li Z , McLaren RG , Metherell A.K. The availability of native and applied soil cobalt to ryegrass in relation to soil cobalt and manganese status and other soil properties. N. Z. J. Agric. Res. 2004;47:3343.
Lin MC , Liao C.M. Assessing the risks on human health associated with inorganic arsenic intake from groundwater-cultured milk fish in southwestern Taiwan. Food Chem. Toxicol. 2008;46:701709.
Lin T , Wan X , Zhang F. The short-term responses of glutathione and phytochelation synthetic pathways genes to additional nitrogen under cadmium stress in poplar leaves. Russ. J. Plant Physiol. 2016;63:754.
Lin T , Zhu X , Zhang F , Wan X. The detoxification effect of cadmium stress in Populus yunnanensis. Res. J. Bot. 2011;4:1319.
Liu WH , Zhao JZ , Ouyang ZY , Sderlund L, Liu GH. Impacts of sewage irrigation on heavy metal distribution and contamination in Beijing, China. Environ. Inter. 2005;31:805812.
Loneragan J.F. Distribution and movement of manganese in plants. In: Manganese in soils and plants. Graham RD , Hannam RJ , Uren NC (Eds.). Kluwer, Dordrecht, 1988;113124.

Lpez Alonso M , Benedito JL , Miranda M , Castillo C , Hernandez J , Shore R.F. Toxic and trace elements in liver, kidney and meat from cattle slaughtered in Galicia (NW Spain). Food Addit. Contam. 2000;17:447457.

95 Maksymiec W , Krupa Z. The in vivo and in vitro influence of methyl jasmonate on oxidative processes in Arabidopsis thaliana leaves. Acta Physiol. Plant. 2002;24:351357.

Malmauret L , Parent-Massin D , Hardy JL , Verger P. Contaminants in organic and conventional foodstuffs in France. Food Addit. Contam. 2002;19:524532.

Manikandan R , Ezhili N , Venkatachalam P. Phosphorus supplementation alleviation of the cadmium-induced toxicity by modulating oxidative stress mechanisms in vetiver grass (Chrysopogon zizanioides (L.) Roberty. J. Environ. Eng. 2016;142:C4016003. doi:10.1061/(ASCE)EE.1943-7870.0001112#sthash.

Marschner H. Mineral Nutrition of Higher Plants, 2nd edn. Academic Press, Toronto, 1995.

Masood A , Iqbal N , Khan N.A. Role of ethylene in alleviation of cadmium-induced photosynthetic capacity inhibition by sulfur in mustard. Plant Cell Environ. 2012;35:524533.

Masuda N , Nakaya S , Burton HR , Torii T. Trace element distributions in some saline lakes of the Vestfold Hills, Antarctica. Hydrobiologia 1988;165:103114.

Matsuoka M. Gibberellins signaling: How do plant cells respond to GA signals?. J. Plant Growth Regul. 2003;22:123125.

Meharg AA , Macnair M.R. Suppression of the high affinity phosphate uptake system; a mechanism of arsenate tolerance in Holcus lanatus L. J. Exp. Bot. 1992;43:519524.

Meharg A.A. Integrated tolerance mechanisms-constitutive and adaptive plant-response to elevated metal concentrations in the environment. Plant Cell Environ. 1994;17:989993.

Messer RL , Lockwood PE , Tseng WY , Edwards K , Shaw M , Caughman GB , Lewis JB , Wataha J.C. Mercury (II) alters mitochondrial activity of monocytes at sublethal doses via oxidative stress mechanisms. J. Biomed. Mat. Res. B 2005;75:257263.

Mhamdi A , Hager J , Chaouch S , Queval G , Han Y , Taconnat L , Saindrenan P , Gouia H , Issakidis-Bourguet E , Renou JP , Noctor G. Arabidopsis glutathione reductase 1 plays a crucial role in leaf responses to intracellular H2O2 and in ensuring appropriate gene expression through both salicylic acid and jasmonic acid signaling pathways. Plant Physiol. 2010;153:1441160.

Millar AH , Mittova V , Kiddle G , Heazlewood JL , Bartoli CG , Theodoulou FL , Foyer C.H. Control of ascorbate synthesis by respiration and its implications for stress responses. Plant Physiol. 2003;133:443447.

Ministry of Agriculture, Fisheries and Food . Survey of aluminium, antimony, chromium, cobalt, indium, nickel, thallium and tin in food. 15. Report of the Steering Group on Food Surveillances; The Working Party on the Monitoring of Foodstuffs for Heavy Metals. Her Majestys Stationery Office, London, 1985.

Mohanpuria P , Rana NK , Yadav S.K. Cadmium induced oxidative stress influence on glutathione metabolic genes of Camella sinensis (L.).OKuntze.Environ.Toxicol. 2007;22:368374.

Mohiuddin KM , Zakir HM , Otomo K , Sharmin S , Shikazono N. Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river. Int. J. Environ. Sci. Tech. 2010;7:1728.

Moller A , Mller HW , Abdullah A , Abdelgawad G , Utermann J. Urban soil contamination in Damascus, Syria: Concentrations and patterns of heavy metals in the soils of the Damascus Ghouta. Geoderma 2005;124:6371.

Morzck E Jr , Funicclli N.A. Effect of lead and on germination of Spartina alterniflora Losiel seeds at various salinities. Environ. Exp. Bot. 1982;22:2332.

Mourato M , Reis R , Martins L.L. Characterization of plant antioxidative system in response to abiotic stresses: A focus on heavy metal toxicity. In: Advances in Selected Plant Physiology Aspects. Montanaro G, . Dichio B (Eds.), InTech, Vienna, Austria, 2012;2344.

Muller M , Anke M , Illing-Gunther H , Thiel H.C. Oral cadmium exposure of adults in Germany. 2: Basket calculations. Food Addit. Contam. 1998;15:135141.

Nakos G. Lead pollution: Fate of lead in soil and its effects on Pinus haplenis. Plant Soil 1979;50:159161.

Nieboer E , Richardson D.H.S. The replacement of the nondescript term heavy metals by a biologically and chemistry significant classification of metal ions. Environ. Pollut. Series B. 1980;1:326.

Nielsen PH , Skagerlind P. Cost-neutral replacement of surfactants with enzymes. Household Pers. Care Today 2007;4:37.

Noctor G , Mhamdi A , Chaouch S , Han YI , Neukermans J , MarquezGarcia B Queval G, Foyer CH. Glutathione in plants: An integrated overview. Plant Cell Environ. 2012;35:454484.

Noctor G , Queval G , Mhamdi A , Chaouch S , Foyer C.H. Glutathione. The Arabidopsis Book 2011;9:e0142.

Norastehnia A , Sajedi RH , Nojavan-Asghari M. Inhibitory effects of methyl jasmonate on seed germination in maize (Zea mays): Effect on -amylase activity and ethylene production. Gen. Appl. Plant Physiol. 2007;33:1323.

Noriega G , Santa Cruz D , Batlle A , Tomaro M , Balestrasse K. Heme oxygenase is involved in the protection exerted by jasmonic acid against cadmium stress in soybean roots. J. Plant Growth Regul. 2012;31:7989.

Nriagu J.O. A silent epidemic of environmental metal poisoning? Environ. Pollut. 1988;50:139161.

Office of Drinking Water. Health AdvisoryChromium. US Environmental Protection Agency, Washington, DC, 1987.

Okada IA , Sukuma AM , Maio FD , Dovidauskas S , Zenebon A. Evaluation of cadmium and lead levels in milk in environmental contamination in the Vale do Paraiba region, southeastern Brazil. Rev. Saude Publica. 1997;31:140143.

Pandey N , Sharma C.P. Effect of heavy metals Co+, Ni+ and Cd+ on growth and metabolism of cabbage. Plant Sci. 2002;163:753758.

Pankovic D , Plesnicar M , Arsenijeevic-Maksimovic I , Petrovic N , Sakac Z , Kastori R. Effects of nitrogen nutrition on photosynthesis in Cd-treated sunflower plants. Ann. Bot. 2000;86:841847.

Papafilippaki AK , Kotti ME , Stavroulakis G.G. Seasonal variations in dissolved heavy metals in the Keritis River, Chania, Greece. Global Nest J. 2008;10:320325.

Pastori GM , Kiddle G , Antoniw J , Bernard S , Veljovic-Jovanovic S , Verrier PJ , Noctor G , Foyer C.H. Leaf vitamin C contents modulate plant defense transcripts and regulate genes that control development through hormone signaling. Plant Cell. 2003;15:939951.

Per TS , Khan NA , Masood A , Fatma M. Methyl Jasmonate alleviates cadmium-induced photosynthetic damages through increased S-assimilation and glutathione production in Mustard. Front Plant Sci. 2016;7:1933.

Peto A , Lehotai N , Lozano-Juste J , Len J , Tari I , Erdei L , Kolbert Z. Involvement of nitric oxide and auxin in signal transduction 96of copper-induced morphological responses in Arabidopsis seedlings. Ann. Bot. 2011;108:449457.

Phillips D.J.H. Arsenic in aquatic organisms: A review of emphasizing chemical speciation. Aqua Toxicol. 1990;16:151186.

Polesskaya OG , Kashirina EI , Alekhina N.D. Changes in the activity of antioxidant enzymes in wheat leaves and roots as a function of nitrogen source and supply. Russ. J. Plant Physiol. 2004;51:615620.

Porter EK , Peterson P.J. Arsenic accumulation by plants on mine waste (United Kingdom). Environ. Pollut. 1975;4:365371.

Pospisilova J , Synkova H , Rulcova J. Cytokinins and water stress. Biol. Planta. 2000;43:321328.

Prajapati SK , Meravi N. Heavy metal speciation of soil and Calotropis procera from thermal power plant area. Proc. Int. Acad. Ecol. Environ. Sci. 2014;4:6871.

Prasad Kvsk , Pardha saradhi P , Sharmila P . Concerted action of antioxidant enzyme and curtailed growth under zinc toxicity in Brassica juncea. Environ. Exp. Bot. 1999;42:110.

Rahman H , Sabreen S , Alam S , Kawai S. Effects of nickel on growth and composition of metal micronutrients in barley plants grown in nutrient solution. J. Plant Nutr. 2005;28:393404.
Ramakrishna B , Rao S.S.R. Foliar application of brassinosteroids alleviates adverse effects of zinc toxicity in radish (Raphanus sativus L.) plants. Protoplasma 2015;252:665667.
Ramakrishna B , Rao S.S.R. Preliminary studies on the involvement of glutathione metabolism and redox status against zinc toxicity in radish seedlings by 28-homobrassinolide. Environ. Exp. Bot. 2013;96:5258.
Rastgoo L , Alemzadeh A , Afsharifar A. Isolation of two novel isoforms encoding zinc- and copper-transporting P1BATPase from Gouan (Aeluropus littoralis). Plant Omics J. 2011;4:377383.
Reddy AM , Kumar SG , Jyotsnakumari G , Thimmanayak S , Sudhakar C. Lead induced changes in antioxidant metabolism of horsegram (Macrotyloma uniflorum (Lam.) Verdc.) and bengalgram (Cicer arietinum L.). Chemosphere 2005;60:97104.
RIWA . De samenstelling van het Rijnwater in 19861987. Composition of the water of the Rhine in 1986 and 1987. Amsterdam, 1989.
Robock A. Volcanic eruptions and climate. Rev. Geophys. 2000;38:191219.
Roca de Togores M , Ferre R , Frigola A.M. Cadmium and lead in infants cereals-electrothermal-atomic-absorption-spectroscopic determination. Sci. Total Environ. 1999;23:197201.
Rodrguez L , Ruiz E , Alonso-Azcrate J , Rincon J. Heavy metal distribution and chemical speciation in tailings and soils around a PbZn mine in Spain. J. Environ. Manage. 2009;90:11061116.
Ros R , Cook David T , Picazo C , Martinez-Cortina I. Nickel and cadmium-related changes in growth, plasma membrane lipid composition, atpase hydrolytic activity and proton pumping of rice (Oryza sativa L. cv. Bahia) shoots. J. Exp. Bot. 1992;43:14751481.
Ross S.M. Toxic Metals in Soilplant Systems. Wiley, Chichester, 1994;469.
Salonen VP , Korkka-Niemi K . Influence of parent sediments on the concentration of heavy metals in urban and suburban soils in Turku, Finland. Appl. Geochem. 2007;22:906918.
Santra SC , Samal AC , Bhattacharya P , Banerjee S , Biswas A , Majumdar J. Arsenic in food chain and community health risk: A study in gangetic West Bengal. Proc. Environ. Sci. 2013;18:213.
Sarwar Saifullah N , Malhi SS , Zia MH , Naeem A , Bibi S , Farida G . Role of mineral nutrition in minimizing cadmium accumulation by plants. J. Sci. Food Agric. 2010;90:925937.
Sayadi MH , Rezaei M.R. Impact of land use on the distribution of toxic metals in surface soils in Birjand city, Iran. Proc. Int. Acad. Ecol. Environ. Sci. 2014;4:1829.
Sayyed MRG , Sayadi M.H. Variations in the heavy metal accumulations within the surface soils from the Chitgar industrial area of Tehran. Proc. Int. Acad. Ecol. Environ. Sci. 2011;1:3646.
Schaum J , Schuda L , Wu C , Sears R , Ferrario J , Andrews K. A national survey of persistent, bioaccumulative, and toxic (PBT) pollutants in the United States supply. J. Expo. Anal. Environ. Epidemiol. 2003;13:177186.
Schmfger M.E.V. Phytochelatins: Complexation of metals and metalloids, studies on the phytochelatin synthase. PhD Thesis, Munich University of Technology (TUM), Munich, 2001.
Seaward MRD , Richardson D.H.S. Atmospheric sources of metal pollution and effects on vegetation. In: Heavy Metal Tolerance in Plants Evolutionary Aspects. Shaw AJ (Eds.). CRC Press, Boca Raton, 1990;7594.
Seregin IV , Kozhevnikova AD , Kazyumina EM , Ivanov V.B. Nickel toxicity and distribution in maize roots. Russ. J. Plant Physiol. 2003;50:711717.
Shanker AK , Djanaguiraman M , Pathmanabhan G , Sudhagar R , Avudainayagam S. Uptake and phytoaccumulation of chromium by selected tree species. In: Proceedings of the International Conference on Water and Environment held in Bhopal, India, 2003.
Shao HB , Chu LY , Lu ZH , Kang C.M. Primary antioxidant free radical scavenging and redox signaling pathways in higher plant cells. Int. J. Biol. Sci. 2008;4:814.
Sharma I , Pati PK , Bhardwaj R. Effect of 28-homobrassinolide on antioxidant defence system in Raphanus sativus L. under chromium toxicity. Ecotoxicology 2011;20:862874.
Sharma I , Pati PK , Bhardwaj R. Regulation of growth and antioxidant enzyme activities by 28-homobrassinolide in seedlings of Raphanus sativus L. under cadmium stress. Indian J. Biochem. Biophys. 2010;47:172177.
Sharma P , Bhardwaj R , Arora N , Arora H.K. Effect of 28- homobrassinolide on growth, zinc metal uptake and antioxidative enzyme activities in Brassica juncea L. seedlings. Braz. J. Plant Physiol. 2007;19:203210.
Sharma P , Dubey R.S. Lead toxicity in plants. Braz. J. Plant Physiol. 2005;17:3552.
Sharma P , Kumar A , Bhardwaj R. Plant steroidal hormone epibrassinolide regulateHeavy metal stress tolerance in Oryza sativa L. by modulating antioxidant defense expression. Environ. Exp. Bot. 2016;122:19.
Sharma SS , Dietz K.J. The significance of amino acids and amino acid-derived mo lecules in plant responses and adaptation to heavy metal stress. J. Exp. Bot. 2006;57:711726.
Shen W , Nada K , Tachibana S. Involvement of polyamines in the chilling tolerance of cucumber cultivars. Plant Physiol. 2000;124:431439.
Shujuan H , Yongjun H , Hongbin W , Haijuan W , Qinchun L. Effects of indole-3-acetic acid on arsenic uptake and antioxidative enzymes in Pteris cretica var. nervosa and Pteris ensiformis. Int. J. Phytoremed. 2017;19:231238.
Simsek O , Gultekin R , Oksuz O , Kurultay S. The effect of environmental pollution on the heavy metal content of raw milk. Nahrung 2000;44:360363.
97 Singh I , Shah, K. Exogenous application of methyl jasmonate lowers the effect of cadmium-induced oxidative injury in rice seedlings. Phytochemistry 2014;31:5766.
Singh R , Singh S , Parihar P , Singh VP , Prasad S.M. Arsenic contamination, consequences and remediation techniques: A review. Ecotoxicol. Environ. Saf. 2015;112:247270.
Singh S , Parihar P , Singh R , Singh VP , Prasad S.M. Heavy metal tolerance in plants: Role of transcriptomics, proteomics, metabolomics, and ionomics. Front. Plant Sci. 2016;6:1143.
Singh VK , Singh KP , Mohan D. Status of heavy metals in water and bed sediments of River GomtiA tributary of the Ganga River, India. Environ. Monit. Assess. 2005;105:4367.
Sinha S , Gupta M , Chandra P. Oxidative stress induced by iron in Hydrilla verticillata (i.f) Royle: Response of antioxidants. Ecotoxicol. Environ. Saf. 1997;38:286291.
Sinha SK , Srinivastava HS , Mishra S.N. Effect of lead on nitrate reductase activity and nitrate assimilation in pea leaves. Bot. Pollut. 1988;57:457463.
Sinha SK , Srinivastava HS , Mishra S.N. Nitrate assimilation in intact and excised maize leaves in the presence of lead. Bull. Environ. Contam. Toxicol. 1988a;41:419422.
Slooff W , Cleven RFMJ , Janus JA , van der Poel P , van Beelen P , Boumans LJM , Canton JH , Eerens HC , Krajnc EI , de Leeuw Faam , Matthijsen Ajcm , van de Meent D , van der Meulen A , Mohn GR , Wijland GC , de Bruijn PJ , van Keulen A , Verburgh JJ , van der Woerd KF . Integrated Criteria Document Chromium. National Institute of Public Health and Environmental Protection, Bilthoven, the Netherlands, 1989.

Smith S.R. Agricultural Recycling of Sewage Sludge and the Environment. CAB International, Wallingford, UK, 1996.
Srivastava S , Dubey R.S. Manganese-excess induces oxidative stress, lowers the pool of antioxidants and elevates activities of key antioxidative enzymes in rice seedlings. Plant Growth Regul. 2011;64:116.
Stadtman ER , Oliver C.N. Metal-catalyzed oxidation of proteins. Physiological consequences. J. Biol. Chem. 1991;266:20052008.
Staessen JA , Lauwerys RR , Ide G , Roels HA , Vyncke G , Amery A. Renal function and historical environmental cadmium pollution from zinc smelters. Lancet 1994;343:15231527.
Storelli MM , Marcotrigiano G.O. Cadmium and total mercury in some Cephalopods from the South Adriatic Sea (Italy). Food Addit. Contam. 1999;16:261265.
Szabados L , Savoure A. Proline: A multifunctional amino acid. Trends Plant Sci. 2010;15:8997 .
Szymszak J , Ilow R , Regulska-Ilow B. Levels of cadmium and lead in vegetables, fruits, cereals and soil from areas differing in the degree of industrial pollution and from green houses. Rocz. Panstw. Zakl. Hig. 1993;44:331346.
Tahvonen R , Kumpalainen J. Lead and cadmium content in Finnish breeds. Food Addit. Contam. 1994;11:621631.
Tahvonen R , Kumpalainen J. Lead and cadmium in some berries on the Finnish market in 19911993. Food Addit. Contam. 1995;12:789798.
Tam E , Miike R , Labrenz S , Sutton AJ , Elias T , Davis J , Chen YL , Tantisira K , Dockery D , Avo E. Volcanic air pollution over the Island of Hawaii: Emissions, dispersal, and composition. Environ. Inter. 2016;9293:543552.
Tchounwou PB , Yedjou CG , Patlolla AK , Sutton DJ . Heavy metals toxicity and the environment. EXS 2012;101:133164.
Tripathi RM , Raghunath R , Sastry VN , Krishnamoorthy V.N. Daily intake of heavy metals in infants through milk and milk products. Sci. Total Environ. 1999;227:229235.
Van Assche F , Clijsters H. Effects of metals on enzyme activity in plants. Plant Cell Environ. 1990;13:195206.
Vanneste S , Friml J. Auxin: A trigger for change in plant development. Cell 2009;136:10051016.
Verkleji J.A.S. The effects of heavy metals stress on higher plants and their use as bio monitors. In: Plant as Bioindicators: Indicators of Heavy Metals in the Terrestrial Environment. Markert B (Eds.). VCH, New York, 1993;415424.
Vos G , Lammers H , Kan C.A. Cadmium and lead in muscles tissue and organs of broilers, turkeys and spent hens and in mechanically deboned poultry meat. Food Addit. Contam. 1990;7:8391.
Wan D , Han Z , Yang Z , Yang G , Liu X. Heavy metal pollution in settled dust associated with different urban functional areas in a heavily air-polluted city in North China. Int. J. Environ. Res. Public Health 2016;13:1119.
Wangeline AL , Burkhead JL , Hale KL , Lindblom SD , Terry N , Pilon M , Pilon-Smits E.A. Over-expression of ATP sulfurylase in Indian mustard: Effects on tolerance and accumulation of twelve metals. J. Environ. Qual. 2004;33:5460.
Wngstrand H , Eriksson J , born I. Cadmium concentration in winter wheat as affected by nitrogen fertilization. Eur. J. Agron. 2007;26:209214.
Watanabe T , Shimbo S , Higashikawa K , Ikeda M. Lead and cadmium content in cereals and pulses in north-eastern China. Sci. Total Environ. 1998;220:137145.
Werner T , Motyka V , Strnad M. , Schmulling T. Regulation of plant growth by cytokinin. Plant Biol. 2001;98:1048710492.
Wilcke W , Krauss M , Kobza J. Concentrations and forms of heavy metals in Slovak soils. J. Plant Nutr. Soil Sci. 2005;168:676686.
Wu S. Effect of manganese excess on the soybean plant cultivated under various growth conditions. J. Plant Nutr. 1994;17:9931003.
Xiang C , Oliver D.J. Glutathione metabolic genes coordinately respond to heavy metals and jasmonic acid in Arabidopsis. Plant Cell 1998;15391550.
Xiao Y , Jalkanen H , Yang Y , Mambote C , Boom R. Ferrovanadium production from petroleum fly ash and BOF flue dust. Min. Eng. 2010;23:11551157.
Yan Z , Zhang W , Chen J , Li X. Methyl jasmonate alleviates cadmium toxicity in Solanum nigrum by regulating metal uptake and antioxidative capacity. Biol. Plant, 2015.59:373381.
Yanqun Z , Yuan L , Jianjun C , Haiyan C , Li Q , Schratz C. Hyper accumulation of Pb, Zn and Cd in herbaceous grown on lead-zinc mining area in Yunnan, China. Env iron. Int. 2005;31:755762.
Yazaki K. ABC transporters involved in the transport of plant secondary metabolites. FEBS Lett. 2006;580:11831191.
Ysart G , Miller P , Crews H , Robb P , Baxter M , de LArgy C , Lofthouse S , Sargent C , Harrison N. Dietary exposure estimates of 30 elements from the UK Total Diet Study. Food Addit. Contam. 1999;16:391403.
Ysart G , Miller P , Croasdale M , Crews H , Robb P , Baxter M , de IArgy C , Harrison N. UK total diet study. Dietary exposures to aluminium, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, tin and zinc. Food Addit. Contam. 2000;17:775786.
98 Yuan H , Huang X. Inhibition of root meristem growth by cadmium involves nitric oxide-mediated repression of auxin accumulation and signalling in Arabidopsis. Plant Cell Environ. 2016;39:120135.
Zanthopolous N , Antoniou V , Nikolaidis E. Copper, zinc, cadmium and lead in sheep grazing in North Greece. Bull. Environ. Contam. Toxicol. 1999;62:691699.
Zarei S , Ehsanpour AA , Abbaspour J. The role of over expression of P5CS gene on proline, catalase, ascorbate peroxidase activity and lipid peroxidation of transgenic tobacco (Nicotiana tabacum L.) plant under in vitro drought stress. J. Cell Mol. Res. 2012;4:4349.
Zeid I.M. Responses of Phaseolus vulgaris to chromium and cobalt treatments. Biol. Planta. 2001;44:111115.
Zhang WH , Tyerman S.D. Inhibition of water channels by HgCl2 in intact wheat root cells. Plant Physiol. 1999;120:849857.
Zhang Y. Biological role of ascorbate in plants. In: Ascorbic Acid in Plants, Zhang Y (Eds.). Springer Briefs in Plant Science, New York, 2013.
Zhang ZC , Chen BX , Qiu B.S. Phytochelatin synthesis plays a similar role in shoots of the cadmium hyperaccumulator Sedum alfredii as in non-resistant plants. Plant Cell Environ. 2010;33:12481255.
Zhang ZW , Watanabe T , Shimbo S , Higashikawa K , Ikeda M. Lead and cadmium content in cereals and pulses in north-eastern China. Sci. Total Environ. 1998;220:137145.
Zhao DL , Reddy KR , Kakani VG , Reddy V.R. Nitrogen deficiency effects on plant growth, leaf photosynthesis, and hyperspectral reflectance properties of sorghum. Eur. J. Agron. 2005;22:391403.
Zheng Y , Chen T , He J. Multivariate geostatistical analysis of heavy metals from Beijing, China. J. Soils Sedim. 2008;8:5158.
Zhou ZS , Huang SQ , Guo K , Mehta SK , Zhang PC , Yang Z.M. Metabolic adaptations to mercury-induced oxidative stress in roots of Medicago sativa L. J. Inorg. Biochem. 2007;101:19.
Zimakowska-Gnoinska D , Bech J , Tobias F.J. Assessment of the heavy metal contamination effects on the soil respiration in the Baix Llobregat (Catalonia, NE Spain). Environ. Monit. Asses. 2000;61:301313.

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Akhtar MW , Sengupta D , Chowdhury A. Impact of pesticides use in agriculture: Their benefits and hazards. Interdiscip Toxicol. 2009; 2: 112.
Ananieva AE , Alexieva VS , Popova L.P. Treatment with salicylic acid decreases the effects of paraquat on photosynthesis. J. Plant Physiol. 2002; 159(7): 685693.
Ananieva AE , Christova KN , Popova L.P. Exogenous treatment with salicylic acid leads to increased antioxidant capacity in leaves of barley plants exposed to Paraquat. J. Plant Physiol. 2004; 161: 319328.
Apel K , Hirt H. Reactive oxygen species: Metabolism, oxidative stress, and signal transduction. Annu. Rev. Plant Biol. 2004; 55: 373399.
Ashraf M , Athar HR , Harris PJC , Kwon T.R. Some prospective strategies for improving crop salt tolerance. Adv. Agron. 2008; 97: 45110.
Bader KP , Abdel-Basset R. Adaptation of plants to anthropogenic and environmental stresses. In: The Effects of Air Constituents and Plant-Protective Chemicals, Handbook of Plant and Crop Stresses, Pessarakli M (Ed.). New York, NY: Marcel Dekker, 1999, pp. 9731010.
Baig KJ , Wagner P , Ananjeva NB , Bohme W. A morphology-based taxonomic revision of Laudakia Gray, 1845 (Squamata: Agamidae). Vertebr. Zool. 2012; 62: 213260.
Bajguz A Hayat S . Effects of brassinosteroids on the plant responses to environmental stresses. Plant Physiol Biochem. 2009; 47: 18.
Ball L , Accotto GP , Bechtold U , Creissen G , Funck D , Jimenez A , Kular B , et al. Evidence for a direct link between glutathione synthesis and stress defence gene expression in Arabidopsis. Plant Cell 2004; 16: 24482462.
Bandurska H. Does proline accumulated in leaves of water deficit stressed barley plants confine cell membrane injuries? II. Proline accumulation during hardening and its involvement in reducing membrane injuries in leaves subjected to severe osmotic stress. Acta Physiol. Plant 2001; 23(4): 483490.
Banerjee BD , Seth V , Ahmed R.S. Pesticide-induced oxidative stress: Perspectives and trends. Rev. Environ. Health. 2001; 16: 140.
Bashir F , Siddiqi TO , Mahmooduzzafar, Iqbal M. Effects of different concentrations of mancozeb on the morphology and anatomy of Lens culina ris L. Ind. J. Environ. Sci. 2007; 11: 7174.
Bashri G , Prasad S.M. Exogenous IAA differentially affects growth, oxidative stress and antioxidants system in Cd stressed Trigonella foenum-graecum L. seedlings: Toxicity alleviation by up-regulation of ascorbate glutathione Cycle. Ecotoxicol. Environ. Saf. 2016; 132: 329338.
Berenbaum, May R. The chemistry of defense: Theory and practice. Proc. Natl. Acad. Sci. 1995; 92(1): 28.
Berkowitz O , De Clercq I , Van Breusegem F , Whelan J. Interaction between hormonal and mitochondrial signalling during growth, development and in plant defence responses. Plant, Cell Environ. 2016; 39: 11271139.
Carvalho F.P. Agriculture, pesticides, food security and food safety. Environ. Sci. Policy 2006; 9: 685692.
Casida JE , Quistad G.B. Organophosphate toxicology: Safety aspects of on acetylcholinesterase secondary targets. Chem Res Toxicol. 2004; 17: 983998.
108 Channapatna S.P. The genetically modified crop debate in the context of agricultural evolution. Plant Physiol. 2001; 126: 815.
Chaudhary SP , Kanwar M , Bhardwaj R , Yu JQ , Tran L.P. Chromium stress mitigation by polyamine-brassinosteroid application involves phytohormonal and physiological strategies in Raphanus sativus L. PLoS One 2012; 7: 33210.
Cherian S , Oliveira M.M. Transgenic plants in phytoremediation: Recent advances and new possibilities. Environ. Sci. Technol. 2005; 39: 93779390.
Cui J , Zhang R , Wu GL , Zhu HM , Yang H. Salicylic acid reduces napropamide toxicity by preventing its accumulation in rapeseed (Brassica napus L.). Arch. Environ. Contam. Toxicol. 2010; 59: 100108.
Dankyi E , Gordon C , Carboo D , Fomsgaard I.S. Quantification of neonicotinoid insecticide residues in soils from cocoa plantations using a QuEChERS extraction procedure and LC-MS/MS. Sci. Total Environ. 2014; 499: 276283.
DeLorenzo ME , Scott GI , Ross P.E. Toxicity of pesticides to aquatic microorganisms: A review. Environ. Toxicol. Chem. 2001; 20: 8498.
Dhaliwal GS , Arora R. Principles of Insect Pest Management. National Agricultural Technology Information Centre, 1996.
Dhaubhadel S , Browning KS , Gallie DR , Krishna P. Brassinosteroid functions to protect the translational machinery and heat-shock protein synthesis following thermal stress. Plant J. 2002; 29: 681691.
Dias M.C. Phytotoxicity: An overview of the physiological responses of plants exposed to fungicides. J. Bot. 2012. doi:10.1155/2012/135479
Dubey G , Mishra N , Prasad S.M. Metabolic responses of pesticides in plants and their ameliorative processes. In: Plant Responses to Xenobiotics, Singh A , Singh RP , Prasad SM (Eds.), Springer Nature Singapore Pte Ltd., 2016.
Durmu N , Bekircan T. Pretreatment with polyamines alleviate the deleterious effects of diuron in maize leaves. Acta Biol. Hung. 2015; 66: 5265.
Essumang DK , Togoh GK , Chokky L. Pesticide residues in the water and fish (Lagoon Tilapia) samples from Lagoons in Ghana. Bull. Chem. Soc. Ethiop. 2009; 23: 1927.
Foyer CH , Noctor G. Redox homeostasis and antioxidant signalling: A metabolic link between stress perception and physiological responses. Plant Cell 2005; 17: 18661875.
Franco R , Li S , Rodriguez-Rocha H , Burns M , Panayiotidis M.I. Molecular mechanisms of pesticide-induced neurotoxicity: Relevance to Parkinsons disease. Chem. Biol. Interact. 2010; 188: 289300.
Franco R , Sanchez-Olea R , Reyes-Reyes EM , Panayiotidis M.I. Environmental toxicity, oxidative stress and apoptosis: Menagea trois. Mutat. Res. 2009; 674: 322.
Freedman B. Environmental Ecology: The Ecological Effects of Pollution, Disturbance, and Other Stresses. San Diego, CA: Academic Press, 1995.
Fufezan C , Rutherford AW , Krieger-Liszkay A. Singlet oxygen production in herbicide-treated photosystem II. FEBS Lett. 2002; 532: 407410.
Gallego-Giraldo L , Escamilla-Trevino L , Jackson LA , Dixon R.A. Salicylic acid mediates the reduced growth of lignin down-regulated plants. Proc. Natl. Acad. Sci. U.S.A. 2011; 108: 2081420819.
Gilden RC , Katie H , Barbara S. Pesticides and health risks. J. Obst. Gynecol. Neonat. Nurs. 2010; 39(1): 103110.
Gill SS , Tuteja N. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol. Biochem. 2010; 48: 909930.
Gomes T , Xie L , Brede O , Solhaug KA , Salbu B , Tollefsen KE . Sensitivity of the green algae Chlamydomonas reinhardtii to gamma radiation: Photosynthetic performance and ROS formation. Aqua Toxicol. 2017; 183: 110.
Gomez JM , Jimenez A , Olmos E , Sevilla F. Location and effects of long-term NaCl stress on superoxide dismutase and ascorbate peroxidase isoenzymes of pea (Pisum sativum cv. Puget) chloroplasts. J. Exp. Bot. 2004; 55: 119130.
Gonzlez-Garca MP , Vilarrasa-Blasi J , Zhiponova M , Divol F , Mora-Ga rca S , Russinova E. Brassinosteroids control meristemsize by promoting cell cycle progression in Arabidopsis roots. Development 2011; 138: 849859.
Guo YP , Zhou HF , Zhang L.C. Photosynthetic characteristics and protective mechanisms against photooxidation during high temperature stress in two citrus species. Sci. Hortic. 2006; 108: 260267.

Haukioja, E.r.kki. Induction of defenses in trees. Annu. Rev. Entomol. 1991; 36(1): 2542.
Hayat S , Fariduddin Q , Ali B , Ahmad A. Effect of salicylic acid on growth and enzyme activities of wheat seedlings. Acta Agron. Hung. 2005; 53: 433437.
Hayat Q , Hayat S , Irfan M , Ahmad A. Effect of exogenous salicylic acid under changing environment: A review. Environ. Exp. Bot. 2010; 68: 1425.
Hayat S , Khalique G , Wani AS , Alyemeni MN , Ahmad A. Protection of growth in response to 28-homobrassinolide under the stress of cadmium and salinity in wheat. Int. J. Biol. Macromol. 2014; 64: 130136.
Honnerova J , Rothova O , Hola D , Koccova M , Kohout L , Kvasnica M. The exogenous application of brassinosteroids to Zea mays (L.) stressed by long-term chilling does not affect the activities of photosystem 1 or 2. J. Plant Growth Regul. 2010; 29(4): 500505.
Hsu YT , Kao C.H. Phosphinothricin tolerance in rice Oryza sativa L. seedlings is associated with elevated abscisic acid in the leaves. Bot. Bull. Acad. Sin. 2004; 45: 4148.
Jaga K , Dharmani C. Sources of exposure to and public health implications of organophosphate pesticides. Pan Am. J. Public Health. 2003; 14: 171185.
Jung S , Chon S , Kuk Y. Differential antioxidant responses in catalase-deficient maize mutants exposed to norflurazon. Biol. Plant 2006; 50: 383388.
Kaushik S , Inderjit S. Phytotoxicity of selected herbicides to mung bean (Phaseolus aureus Roxb.). Environ. Exp. Bot. 2006; 55: 4148.
Kawano T. Roles of the reactive oxygen species-generating peroxidase reactions in plant defense and growth induction. Plant Cell Rep. 2003; 21: 829837.
Kaya A , Yigit E. The physiological and biochemical effects of salicylic acid on sunflowers (Helianthus annuus) exposed to flurochloridone. Ecotox. Environ. Saf. 2014; 106: 232238.
Khan MS , Chaudhary P , Wani PA , Zaidi A. Biotoxic effects of the herbicides on growth, seed yield and grain protein of green gram. J. Appl. Sci. Environ. Manage. 2006; 10: 141146.
Kilic S , Duran RE , Coskun Y. Morphological and physiological responses of maize (Zea mays L.) seeds grown under increasing concentrations of chlorantraniliprole insecticide. Pol. J. Environ. Stud. 2015; 3: 10691075.
109 Kleijn G , Snoeijing I.J. Field boundary vegetation and the effects of agrochemical drift: Botanical change caused by low levels of herbicide and fertilizer. J. Appl. Ecol. 1997; 34: 14131425.
Kumar S , Singh A. Biopesticides: Present status and the future prospects. J. Biofertil. Biopest. 2015; 6: 129.
Li J , Zhao X , Matsui S , Maezawa S. Changes in antioxidative levels in aging cucumber (Cucumis sativus L.) leaves. J. Jpn. Soc. Hort. Sci. 2004; 73: 491495.
Liang Lu , Yan Li Lu , Hong Yang . Toxicology of isoproturon to the food crop wheat as affected by salicylic acid. Environ. Sci. Pollut. Res. 2012; 19(6): 20442054.
Liu H , Weisman D , Ye YB , Cui B , Huang YH , Colon-Carmona A , Wang Z.H. An oxidative stress response to polycyclic aromatic hydrocarbon exposure is rapid and complex in Arabidopsis thaliana. Plant Sci. 2009; 176: 375382.
Marcacci S , Raveton M , Ravenel P , Schwitzguebel J. Conjugation of atrazine in vetiver (Chrysopogon zizanioides Nash) grown in hydroponics. Environ. Exp. Bot. 2006; 56(2): 205215.
M Rivas-San Vicente , J Plasencia . Salicylic acid beyond defence: Its role in plant growth and development. J. Exp. Bot. 2011; 62: 33213338.
Mishra V , Srivastava G , Prasad SM , Abraham G. Growth , photosynthetic pigments and photosynthetic activity during seedling stage of cowpea (Vigna unguiculata) in response to UV-B and dimethoate. Pest. Biochem. Physiol. 2008; 92: 3037.
Mittler R , Vanderauwera S , Gollery M , Van Breusegem F. Reactive oxygen gene network of plants. Trends Plant Sci. 2004; 9: 490498.
Murthy GP , Prasad GM , Sudarshana M.S. Toxicity of different imbibition periods of dimethoate on germination, chlorophyll a/b and dry matter of Glycine max (L.) Merrill. cv. KHSB-2, during early seedling growth. J. Physiol. Res. 2005; 18: 199201.
Nason MA , Farrar J , Bartlett D. Strobilurin fungicides induce changes in photosynthetic gas exchange that do not improve water use efficiency of plants grown under conditions of water stress. Pest. Manage. Sci. 2007; 63: 11911200.
Ogweno JO , Song XS , Hu WH , Shi K , Zhou YH , Yu J.Q. Detached leaves of tomato differ in their photosynthetic physiological response to moderate high and low temperature stress. Sci. Hortic. 2009; 123: 1722.
Panduranga G , Prasad GM , Sudarshana M.S. Toxicity of different imbibition periods of dimethoate on germination, chlorophyll a/b and dry matter of Glycine max (L.) Merrill. cv. KHSB-2, during early seedling growth. J. Physiol. Res. 2005; 18: 199201.
Pandya U , Saraf M. Application of fungi as a biocontrol agent and their biofertilizer potential in agriculture. J. Adv. Dev. Res. 2010; 1(1): 9099.
Parween T , Jan S , Mahmooduzzafar S , Fatma T , Siddiqui Z.H. Selective effect of pesticides on plantA review. Crit. Rev. Food Sci. Nut. 2016; 56(1): 160179.
Petit N , Fontaine F , Clement C , Vaillant-Gaveau N. Photosynthesis limitations of grape vine after treatment with the fungicide fludioxonil. J. Agric. Food Chem. 2008; 56: 67616767.
Pinol R , Esther S. Protective Effects of Brassinosteroids Against Herbicides. Brassinosteroids: A Class of Plant Hormone. The Netherlands: Springer, 2011; pp. 309344.
Pinol R , Simon E. Effect of 24-epibrassinolide on chlorophyll fluorescence and photosynthetic CO2 assimilation in Vicia faba plants treated with the photosynthesis inhibiting herbicide terbutryn. J. Plant Growth Regul. 2009; 28: 97105.
Popova LP , Ananieva EA , Alexieva V.S. Treatment with salicylic acid decreases the effects of paraquat on photosynthesis. J. Plant Physiol. 2002; 159: 685693.
Popova LP , Ananieva EA , Christov K.N. Exogenous treatment with salicylic acid leads to increased antioxidant capacity in leaves of barley plants exposed to Paraquat. J. Plant Physiol. 2004; 61: 319328.
Prasad SM , Dwivedi R , Zeeshan M. Growth, photosynthetic electron transport, and antioxidant responses of young soybean seedlings to simultaneous exposure of nickel and UV-B stress. Photosynthetica 2005; 43: 177185.
Prasad SM , Kumar S , Parihar P , Singh A , Singh R. Evaluating the combined effects of pretilachlor and UV-B on two Azolla species. Pest. Biochem Physiol. 2016; 128: 4556. doi:10.1016/j.pestbp.2015.10.006
Radetski CM , Sylvie C , Jean-Franois F. Classical and biochemical endpoints in the evaluation of phytotoxic effects caused by the herbicide trichloroacetate. Environ. Exp. Bot. 2000; 44(3): 221229.
Radwan D.E.M. Salicylic acid induced alleviation of oxidative stress caused by clethodim in maize (Zea mays L.) leaves. Pest. Biochem. Physiol. 2012; 102: 182188.
Raja W , Rathaur P , John SA , Ramteke P.W. Endosulfan induced changes in growth rate, pigment composition and photosynthetic activity of mosquito fern Azolla microphylla. J. Stress Physiol. Biochem. 2012; 8: 98109.
Ramakrishna A , Ravishankar G.A. Influence of abiotic stress signals on secondary metabolites in plants. Plant Sig. Behav. 2011; 6: 17201731.
Ramakrishna A , Ravishankar G.A. Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Climate Change and Plant Abiotic Stress Tolerance, Tuteja N, Gill SS (Eds.), Wiley-VCH Verlag

GmbH & Co. KGaA, 2013; pp. 705 705.

Ramel F , Sulmon C , Bogard M , Couee I , Gouesbet G. Differential dynamics of reactive oxygen species and antioxidative mechanisms during atrazine injury and sucrose-induced tolerance in Arabidopsis thaliana plantlets. BMC Plant Biol. 2009; 9: 28.

Ramel F , Sulmon C , Cabello-Hurtado F , Taconnat L , Martin-Magniette ML , Renou JP , El Amrani A , Couee I , Gouesbet G. Genome-wide interacting effects of sucrose and herbicide-mediated stress in Arabidopsis thaliana: Novel insights into atrazine toxicity and sucrose-induced tolerance. BMC Genom. 2007; 8: 450.

Rio AD , Bamberg J , Centeno-Diaz R , Salas A , Roca W , Tay D. Effects of the pesticide furadan on traits associated with reproduction in wild potato species. Am. J. Plant Sci. 2012; 3: 16081612.

Rodriguez R , Redman R. Balancing the generation and elimination of reactive oxygen species. Proc. Natl. Acad. Sci. 2005; 102: 31753176.

Ryter SW , Kim HP , Hoetzel A , Park JW , Nakahira K , Wang X , Choi A.M. Mechanisms of cell death in oxidative stress. Antioxid. Redox Signal. 2007; 9: 4989.

Sakhabutdinova AR , Fatkhutdinova DR , Bezrukova MV , Shakirova F.M. Salicylic acid prevents damaging action of stress factors on wheat plants. Bulg. J. Plant Physiol. 2003; 314319.

Saladin G , Magne C , Clement C , Effects of fludioxonil and pyrimethanil, two fungicides used against Botrytis cinerea, on carbohydrate physiology in Vitis vinifera L. Pest. Manage. Sci. 2003; 59: 10831092.

110 Saraf M , Sood N. Influence of monocrotophos on growth oxygen uptake and exopolysaccharide production of Rhizobium NCIM 2771 on chickpea. J. Indian Bot. Soc. 2002; 82: 157164.

Sasse J.M. Physiological actions of brassinosteroids: An update. J. Plant Growth Regul. 2003; 22: 276288.

Sergiev IG , Alexieva VS , Ivanov SV , Moskova II , Karanov E.N. The phenyl urea cytokinin 4PU-30 protects maize plants against glyphosate action. Pest. Biochem. Physiol. 2006; 85: 139 139.

Shao H-B , Chu L-Y , Lu Z-H , Kang C-M. Primary antioxidant free radical scavenging and redox signaling pathways in higher plant cells. Int. J. Biol. Sci. 2008; 4: 814.

Sharma A , Kumar V , Singh R , Thukral AK , Bhardwaj R. Effect of seed pre-soaking with 24-epibrassinolide on growth and photosynthetic parameters of Brassica juncea L. in imidacloprid soil. Ecotoxicol. Environ. Saf. 2016a; 133: 195201.

Sharma A , Kumar V , Thukral AK , Bhardwaj R. Epibrassinolide imidacloprid interaction enhances non-enzymatic antioxidants in Brassica juncea L. Ind. J. Plant Physiol. 2016b; 21: 7075. doi:10.1007/s40502-016-0203-x

Sharma A , Thakur S , Kumar V , Kesavan AK , Thukral AK , Bhardwaj R. 24-epibrassinolide stimulates imidacloprid detoxification by modulating the gene expression of Brassica juncea L. BMC Plant Biol. 2017; 17: 56.

Sharma I , Bhardwaj R , Pati P.K. Exogenous application of 28-homobrassinolide modulates the dynamics of salt and pesticides induced stress responses in an elite rice variety Pusa Basmati-1. J. Plant Growth Regul. 2015; 34: 509518.

Sharma I , Bhardwaj R , Pati P.K. Mitigation of adverse effects of chlorpyrifos by 24-epibrassinolide and analysis of stress markers in a rice variety Pusa Basmati-1. Ecotoxicol. Environ. Saf. 2012; 85: 72 72.

Sharma I , Bhardwaj R , Pati P.K. Stress modulation response of 24-epibrassinolide against imidacloprid in an elite indica rice variety Pusa Basmati-1. Pest. Biochem. Physiol. 2013; 105: 144 144.

Singh H , Singh NB , Singh A , Hussain I , Yadav V. Physiological and biochemical effects of salicylic acid on Pisum sativum exposed to isoproturon. Arch. Agron. Soil Sci. 2016; 62: 14251436.

Singh S , Prasad S.M. Growth, photosynthesis and oxidative responses of Solanum melongena L. seedlings to cadmium stress: Mechanism of toxicity amelioration by kinetin. Sci. Hort. 2014; 176: 110.

Soaresa C , Alexandra de Sousa A , Pinto A , Azenha M , Teixeira J , Antunes Azevedoc R , Fidalgo F . Effect of 24-epibrassinolide on ROS content, antioxidant system, lipid peroxidation and Ni uptake in Solanum nigrum L. under Ni stress. Environ. Exp. Bot. 2016; 122: 115125.

Stevens MM , Reinke RF , Coombes NE , Helliwell S , Mo J. Influence of imidacloprid seed treatments on rice germination and early seedling growth. Pest. Manage. Sci. 2008; 64: 215222.

Szabados L , Arnould S. Proline: A multifunctional amino acid. Trends Plant Sci. 2010; 15(2): 8997.

Takagi D , Ishizaki K , Hanawa H , Mabuchi T , Shimakawa G , Yamamoto H , Miyake C. Diversity of strategies for escaping reactive oxygen species production within photosystem I among land plants: P700 oxidation system is prerequisite for alleviating photoinhibition in photosystem I. Physiol. Plant. 2017; 161: 5674. doi:10.1111/ppl.12562

Tebourbi O , Mohsen S , Khemais B.R. Molecular mechanisms of pesticide toxicity. Pesticides in the Modern World-Pests Control and Pesticides Exposure and Toxicity Assessment. InTech, 2011.

Thounaojam TC , Panda P , Mazumdar P , Kumar D , Sharma GD , Sahoo L. Excess copper induced oxidative stress and response of antioxidants in rice. Plant Physiol. Biochem. 2012; 53: 3339.

Untiedt R , Blanke M.M. Effects of fungicide and insecticide mixtures on apple tree canopy photosynthesis, dark respiration and carbon economy. Crop Prot. 2004; 23: 10011006.

Unver T , Bakar M , Shearman RC , Budak H. Genome-wide profiling and analysis of Festuca arundinacea miRNAs and transcriptomes in response to foliar glyphosate application. Mol. Genet. Genom. 2010; 283: 397413.

Wang C , Zhang Q. Exogenous salicylic acid alleviates the toxicity of chlorpyrifos in wheat plants (Triticum aestivum). Ecotoxicol. Environ. Saf. 2017; 137: 218224.

Wang P , Du Y , Li Y , Ren D , Song CP . Hydrogen peroxide-mediated activation of MAP kinase 6 modulates nitric oxide biosynthesis and signal transduction in Arabidopsis. Plant Cell 2010; 22: 29812998.

Wang Y , Ying J , Kuzma M , Chalifoux M , Sample A , McArthur C , Uchacz T , Sarvas C , Wan J , Dennis D.T. Molecular tailoring of farnesylation for plant drought tolerance and yield protection. Plant J. 2005; 43: 413424.

WHO . Joint FAO/WHO Expert Standards Program. Codex Alimentation Commission, Geneva, Switzerland, 2007. Available online http://www.who.int_[accessed 10/09/2012].

Wu XY , Von Tiedemann A. Impact of fungicides on active oxygen species and antioxidant enzymes in spring barley (Hordeum vulgare L.) exposed to ozone. Environ Pollut. 2002; 116: 3747.

Xia XJ , Huang YY , Wang L , Huang LF , Yu YL , Zhou Y.H. Pesticides-induced depression of photosynthesis was alleviated by 24-epibrassinolide pretreatment in Cucumis sativus L. Pest. Biochem. Physiol. 2006; 86: 4248.

Xia XJ , Zhang Y , Wu JX , Wang JT , Zhou YH , Shi K. Brassinosteroids promote metabolism of pesticides in cucumber. J. Agric. Food Chem. 2009; 57: 8406 8406.

Xie L , Yang C , Wang X . Brassinosteroids can regulate cellulose biosynthesis by controlling the expression of CESA genes in Arabidopsis. J. Exp. Bot. 2011; 62: 495506.

Xiong, Y.a.n. Degradation of oxidized proteins by autophagy during oxidative stress in Arabidopsis. Plant Physiol. 2007; 143(1): 291299.

Xu S , Li J , Zhang X , Wei H , Cui L. Effects of heat acclimation pretreatment on changes of membrane lipid peroxidation, antioxidant metabolites, and ultrastructure of chloroplasts in two cool-season turfgrass species under heat stress. Environ. Exp. Bot. 2006; 56: 274 274.

Yigit E , Akbulut GB , Bayram D , Kaya A , Gok Y. Effect of salicylic acid and selenium on antioxidant system of Avena sativa L. under fenoxaprop-p-ethyl stress. Fresen Environ. Bull. 2016; 25: 874884.
Yueh, LY , David L. Hensley . Pesticide effect on acetylene reduction and modulation by soybean and lima bean. J. Am. Soc. Hortic. Sci. 1993; 118(1): 7376.
Zhang ZB , Xu P , Jia JZ , Zhou R.H. Quantitative trait loci for leaf chlorophyll fluorescence traits in wheat. Aust. J. Crop Sci. 2010; 4: 571579.
Zhang ZL , Wei N , Wu Qx , Ping M.L. Antioxidant response of Cucumis sativus L. to fungicide carbendazim. Pest. Biochem. Physiol. 2007; 89: 5459.
Zhou Y , Xia X , Yu G , Wang J , Wu J , Wang M , Yang Y , Shi K , Yu Y , Chen Z , Gan J , Yu J. Brassinosteroids play a critical role in the regulation of pesticide metabolism in crop plants. Sci. Rep. 2015; 5: 9018.

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AbdElgawad, H. , Zinta, G. , Hegab, M. , Pandey, R. , Asard, H. , and Abuelsoud, W. 2016. High salinity induces different oxidative stress and antioxidant responses in maize seedling organs. Front. Plant Sci. 7:276. doi:10.3389/fpls.2016.00276.
Agati, G. , Azzarello, E. , Pollastri, S. , and Tattini, M. 2012. Flavonoids as antioxidants in plants: Location and functional significance. Plant Sci. 196:6776.
Ali, B. , Deng, X. , Hu, X. , et al. 2015. Deteriorative effects of cadmium stress on antioxidant system and cellular structure in germinating seeds of Brassica napus L. J. Agric. Sci. Technol. 17:6374.
Almeras, E. , Stolz, S. , Vollenweider, S. , et al. 2003. Reactive electrophile species activate defense gene expression in Arabidopsis. Plant J. 34:205216.
Al-Taweel, K. , Iwaki, T. , Yabuta, Y. , Shigeoka, S. , Murata, N. , and Wadano, A. 2007. A bacterial transgene for catalase protects translation of D1 protein during exposure of salt-stressed tobacco leaves to strong light. Plant Physiol. 145:258265.
Arrigoni, O. , and De Tullio, M. C. 2000. The role of ascorbic acid in cell metabolism: Between genedirected functions and unpredictable chemical reactions. J. Plant Physiol. 157:481488.
Ashraf, M. A. , Ashraf, A. , and Ali, Q. 2010. Response of two genetically diverse wheat cultivars to salt stress at different growth stages: Leaf lipid peroxidation and phenolic content. Pak. J. Bot. 42:559565.
Bahin, E. , Bailly, C. , Sotta, B. , Kranner, I. , Corbineau, F. , and Leymarie, J. 2011. Crosstalk between reactive oxygen species and hormonal signalling pathways regulates grain dormancy in barley. Plant Cell Environ. 34:980993.
Bari, R. , Jonathan, D. , and Jones, G. 2009. Role of plant hormones in plant defence responses. Plant Mol. Biol. 69:473488.
Bashir, K. , Nagasaka, S. , Itai, R. N. , et al. 2007. Expression and enzyme activity of glutathione reductase is upregulated by Fe-deficiency in graminaceous plants. Plant Mol. Biol. 65:277284.
Bergmann, H. , Leinhos, V. , and Machelett, B. 1994. Increase of stress resistance in crop plants by using phenolic compounds. Acta Hort. 381:390397.
Bolouri-Moghaddam, M. R. , Roy, K. L. , Xiang, L. , Rolland, F. , and Van den Ende, W. 2010. Sugar signalling and antioxidant network connections in plant cells. FEBS J. 277:20222037.
Bonekamp, N. A. , Volkl, A. , Fahimi, H. D. , and Schrader, M. 2009. Reactive oxygen species and peroxisomes: Struggling for balance. Biofactors 35:346355.
Borsani, O. , Daz, P. , Agius, M. F. , Valpuesta, V. , and Monza, J. 2001. Water stress generates an oxidative stress through the induction of a specific Cu/Zn superoxide dismutase in Lotus corniculatus leaves. Plant Sci. 161:757763.
Cambroll, J. , Garca, J. L. , Figueroa, M. E. , and Cantos, M. 2015. Evaluating wild grapevinetolerance to copper toxicity. Chemosphere 120:171178.
Cambrolle, J. , Garcia, J. L. , Ocete, R. , Figueroa, M. E. , and Cantos, M. 2013. Growth and photosynthetic responses to copper in wild grapevine. Chemosphere 93:294301.
Caverzan, A. , Casassola, A. , and Brammer, S. P. 2016. Reactive oxygen species and antioxidant enzymes involved in plant tolerance to stress. In Abiotic and Biotic Stress in Plants: Recent Advances and Future Perspectives, ed. A. K. Shanker , and C. Shanker , 80463. Rijeka, Croatia: InTech.
Chaves, M. M. , Maroco, J. P. , and Pereira, J. S. 2003. Understanding plant responses to drought-from genes to the whole plant. Funct. Plant Biol. 30:239264.
Cheng, M. C. , Ko, K. , Chang, W. L. , Kuo, W. C. , Chen, G. H. , and Lin, T. P. 2015. Increased glutathione contributes to stress tolerance and global translational changes in Arabidopsis. Plant J. 83:926939.
Czegeny, G. , Wu, M. , Der, A. , Eriksson, L. A. , Strid, A. , and Hideg, E. 2014. Hydrogen peroxide contributes to the ultraviolet-B (280315 nm) induced oxidative stress of plant leaves through multiple pathways. FEBS Lett. 588:22552261.
Czuj, T. , Zuk, M. , Starzycki, M. , Amir, R. , and Szopa, J. 2009. Engineering increases in sulfur amino acid contents in flax by overexpressing the yeast Met25 gene. Plant Sci. 177:584592.
Dai, J. , and Mumper, R. 2010. Plant phenolics: Extraction, analysis and their antioxidant and anticancer properties. Molecules 15:73137352.
Dar, T. A. , Uddin, M. , Khan, M. M. A. , Hakeem, K. R. , and Jaleel, H. 2015. Jasmonates counter plant stress: A review. Environ. Exp. Bot. 115:4957.
Daryanto, S. , Wang, L. , and Jacinthe, P. A. 2016. Global synthesis of drought effects on maize and wheat production. PLoS One 11:111.
Deb, R. , and Nagotu, S. 2017. Versatility of peroxisomes: An evolving concept. Tissue Cell 49:209226.
Debolt, S. , Melino, V. , and Ford, C. M. 2007. Ascorbate as a biosynthetic precursor in plants. Ann. Bot. 99:38.
Denness, L. , McKenna, J. F. , Segonzac, C. , et al. 2011. Cell wall damage-induced lignin biosynthesis is regulated by a reactive oxygen species- and jasmonic acid-dependent process in Arabidopsis. Plant Physiol. 156:13641374.
Devi, R. , Kaur, N. , and Gupta, A. K. 2012. Potential of antioxidant enzymes in depicting drought tolerance of wheat (Triticum aestivum L.). Indian J. Biochem. Biophys. 49:257265.
Do, H. , Kim, I. S. , Jeon, B. W. , et al. 2016. Structural understanding of the recycling of oxidized ascorbate by dehydroascorbate reductase (OsDHAR) from Oryza sativa L. Japonica. Sci. Rep. 6:19498. doi:10.1038/srep19498.
Edwards, E. A. , Rawsthorne, S. , and Mullineaux, P. M. 1990. Subcellular distribution of multiple forms of glutathione reductase in leaves of pea (Pisum sativum L.). Planta 180:278284.
Ellouzi, H. , Hamed, K. B. , Cela, J. , Mller, M. , Abdelly, C. , and Munn-Bosch, S. 2013. Increased sensitivity to salt stress in tocopherol-deficient Arabidopsis mutants growing in a hydroponic system. Plant Signal. Behav. 8:e23136. doi:10.4161/psb.23136.
ElSayed, A. I. , Rafudeen, M. S. , and Golldack, D. 2014. Physiological aspects of raffinose family oligosaccharides in plants: Protection against abiotic stress. Plant Biol. 16:18.

Eltayeb, A. E. , Kawano, N. , Badawi, G. H. , et al. 2007. Overexpression of monodehydroascorbate reductase in transgenic tobacco confers enhanced tolerance to ozone, salt and polyethylene glycol stresses. Planta 225:12551264.

122 Fahad, S. , Bajwa, A. A. , Nazir, U. , et al. 2017. Crop production under drought and heat stress: plant responses and management options. Front. Plant Sci. 8:116.

Fahad, S. , Hussain, S. , Matloob, A. , et al. 2015. Phytohormones and plant responses to salinity stress: A review. Plant Growth Regul. 75:391404.

Feng, K. , Yu, J. , Cheng, Y. , et al. 2016. The SOD gene family in tomato: Identification, phylogenetic relationships, and expression patterns. Front. Plant Sci. 7:1279. doi:10.3389/fpls.2016.01279.

Foyer, C. H. , Neukermans, J. , Queval, G. , Noctor, G. , and Harbinson, J. 2012. Photosynthetic control of electron transport and the regulation of gene expression. J. Exp. Bot. 63:16371661.

Foyer, C. H. , and Noctor, G. 2003. Redox sensing and signaling associated with reactive oxygen in chloroplasts, peroxisomes and mitochondria. Physiol. Plant 119:355364.

Foyer, C. H. , and Shigeoka, S. 2011. Understanding oxidative stress and antioxidant functions to enhance photosynthesis. Plant Physiol. 155:93100.

Frova, C. 2003. The plant glutathione transferase gene family: Genomic structure, functions, expression and evolution. Physiol. Plant 119:469479.

Gadjev, I. , Vanderauwera, S. , Gechev, T. , et al. 2006. Transcriptomic footprints disclose specificity of reactive oxygen species signaling in Arabidopsis. Plant Physiol. 141:434445.

Gaspar, T. , Penel, C. , Hagege, D. , and Greppin, H. 1991. Peroxidase in plant growth, differentiation and developmental processes. In Biochemical, Molecular and Physiological Aspects of Plant Peroxidases, ed. J. Lobarzewski , H. Greppin , C. Pennel , and T. Gaspar , 249280. Switzerland: Geneva University Press.

Gharibi, S. , Tabatabaei, B. E. S. , Saeidi, G. , and Goli, S. A. H. 2016. Effect of drought stress on total phenolic, lipid peroxidation, and antioxidant activity of Achillea species. Appl. Biochem. Biotechnol. 178:709796.

Gharsallah, C. , Fakhfakh, H. , Grubb, D. , and Gorsane, F. 2016. Effect of salt stress on ion concentration, proline content, antioxidant enzyme activities and gene expression in tomato cultivars. AoB Plants 8:plw055. doi:10.1093/aobpla/plw055.

Gichner, T. , Patkova, Z. , Szakova, J. , and Demnerova, K. 2004. Cadmium induces DNA damages in tobacco roots, but no DNA damage, somatic mutations or homologous recombinations in tobacco leaves. Mutat. Res. Genet. Toxicol. Environ. Mut. 559:4957.

Gill, S. S. , Anjum, N. A. , Hasanuzzaman, M. , et al. 2013. Glutathione and glutathione reductase: A boon in disguise for plant abiotic stress defense operations. Plant Physiol. Biochem. 70:204212.

Gill, S. S. , and Tuteja, N. 2010. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol. Biochem. 48:909930.

Girotto, E. , Ceretta, C. A. , Rossato, L. V. , et al. 2013. Triggered antioxidant defense mechanism in maize grown in soil with accumulation of Cu and Zn due to intensive application of pig slurry. Ecotox. Environ. Saf. 93:145155.

Govind, S. R. , Jogaiah, S. , Abdelrahman, M. , Huntrike, S. S. , and Tran, L. S. 2016. Exogenous trehalose treatment enhances the activities of defense-related enzymes and triggers resistance against downy mildew disease of pearl millet. Front. Plant Sci. 7:1593. doi:10.3389/fpls.2016.01593.

Hara, M. , Furukawa, J. , Sato, A. , Mizoguchi, T. , and Miura, K. 2012. Abiotic stress and role of salicylic acid in plants. In Abiotic Stress Responses in Plants, ed. A. Parvaiz , and M. N. V. Prasad , 235351. New York: Springer.

Harrison, M. A. 2012. Cross-talk between phytohormone signaling pathways under both optimal and stressful environmental conditions. In Phytohormones and Abiotic Stress Tolerance in Plants, ed. N. A. Khan , R. Nazar , N. Iqbal , and N. A. Anjum , 4976. Berlin/Heidelberg: Springer.

Hayat, S. , Hayat, Q. , Alyemeni, M. N. , Wani, A. S. , Pichtel, J. , and Ahmad, A. 2012. Role of proline under changing environments. Plant Signal. Behav. 7:14561466.

Hernandez, M. N. , Fernandez, G. P. D. , and Olmos, E. 2010. A different role for hydrogen peroxide and the antioxidative system under short and long salt stress in Brassica oleracea roots. J. Exp. Bot. 61:521535.

Heyneke, E. , Luschin-Ebengreuth, N. , Krajcer, I. , Wolkinger, V. , Mller, M. , and Zechmann, B. 2013. Dynamic compartment specific changes in glutathione and ascorbate levels in Arabidopsis plants exposed to different light intensities. BMC Plant Biol. 13:104123.

Hideg, E. , Jansen, M. A. K. , and Strid, A. 2013. UV-B exposure, ROS, and stress: Inseparable companions or loosely linked associates? Trends Plant Sci. 18:107115.

Hong, C. Y. , Hsu, Y. T. , Tsai, Y. C. , and Kao, C. H. 2007. Expression of ascorbate peroxidase 8 in roots of rice (Oryza sativa L.) seedlings in response to NaCl. J. Exp. Bot. 58:32733283.

Jeong, Y. C. , Nakamura, J. , Upton, P. B. , and Swenberg, J. A. 2005. Pyrimido[1,2-]-purin-10(3H)-one, M1G, is less prone to artifact than base oxidation. Nucl. Acids Res. 33:64266434.

Jinadasa, N. , Collins, D. , Holford, P. , Milham, P. J. , and Conroy, J. P. 2016. Reactions to cadmium stress in a cadmium-tolerant variety of cabbage (Brassica oleracea L.): Is cadmium tolerance necessarily desirable in food crops. Environ. Sci. Pollut. Res. 23:52965306.

Jisha, K. C. , and Puthur, J. T. 2014. Halopriming of seeds imparts tolerance to NaCl and PEG induced stress in Vigna radiata (L.) Wilczek varieties. Physiol. Mol. Biol. Plants 20:303312.

Jogeswar, G. , Pallela, R. , Jakka, N. M. , et al. 2006. Antioxidative response in different sorghum species under short-term salinity stress. Acta Physiol. Plant 28:465475.

Jozefczak, M. , Remans, T. , Vangronsveld, J. , and Cuypers, A. 2012. Glutathione is a key player in metal-induced oxidative stress defenses. Int. J. Mol. Sci. 13:31453175.

Jumali, S. S. , Said, I. M. , Ismail, I. , and Zainal, Z. 2011. Genes induced by high concentration of salicylic acid in Mitragyna speciosa. Aust. J. Crop Sci. 5:296303.

Kang, L. , Park, S. , Ji, C. Y. , Kim, H. S. , Lee, H. , and Kwak, S. 2017. Metabolic engineering of carotenoids in transgenic sweet potato. Breed Sci. 67:2734.

Kaniuga, Z. 2008. Chilling response of plants: Importance of galactolipase, free fatty acids and free radicals. Plant Biol. 10:171184.

Kapoor, D. , Sharma, R. , Handa, N. , et al. 2015. Redox homeostasis in plants under abiotic stress: Role of electron carriers, energy metabolism mediators and proteinaceous thiols. Front. Environ. Sci. 3:13. doi:10.3389/fenvs.2015.00013.

Kasote. D. M. , Katyare. S. S. , Hegde. M. V. , and Bae. H. 2015. Significance of antioxidant potential of plants and its relevance to therapeutic applications. Int. J. Biol. Sci. 11:982991.

123 Katsuhara, M. , Otsuka, T. , and Ezaki, B. 2005. Salt stress-induced lipid peroxidation is reduced by glutathione S-transferase, but this reduction of lipid peroxides is not enough for a recovery of root growth in Arabidopsis. Plant Sci. 169:369373.

Keunen, E. , Peshev, D. , Vangronsveld, J. , Van Den Ende, W. , and Cuypers, A. 2013. Plant sugars are crucial players in the oxidative challenge during abiotic stress: Extending the traditional concept. Plant Cell Environ. 36:12421255.

Kim, J. H. , Moon, J. Y. , Park, E. Y. , Lee, K. H. , and Hong, Y. C. 2011. Changes in oxidative stress biomarker and gene expression levels in workers exposed to volatile organic compounds. Ind. Health 49:814.

Kim, Y. H. , Kim, C. Y. , Song, W. K. , et al. 2008. Overexpression of sweetpotato swpa4 peroxidase results in increased hydrogen peroxide production and enhances stress tolerance in tobacco. Planta 227:867881.

Kliebenstein, D. J. , Dietrich, R. A. , Martin, A. C. , Last, R. L. , and Dangl, J. L. 1999. LSD1 regulates salicylic acid induction of copper zinc superoxide dismutase in Arabidopsis thaliana. Mol. Plant Microbe Interact. 12:10221026.

Koussevitzky, S. , Suzuki, N. , Huntington, S. , et al. 2008. Ascorbate peroxidase 1 plays a key role in the response of Arabidopsis thaliana to stress combination. J. Biol. Chem. 283:3419734203.

Ksouri, R. , Megdiche, W. , Falleh, H. , et al. 2008. Influence of biological, environmental and technical factors on phenolic content and antioxidant activities of Tunisian halophytes. C. R. Biol. 331:865873.

Lee, Y. P. , Kim, S. H. , Bang, J. W. , Lee, H. S. , Kwak, S. S. , and Kwon, S. Y. 2007. Enhanced tolerance to oxidative stress in transgenic tobacco plants expressing three antioxidant enzymes in chloroplasts. Plant Cell Rep. 26:591598.

Lesk, C. , Rowhani, P. , and Ramankutty, N. 2016. Influence of extreme weather disasters on global crop production. Nature 529:8487.

Lu, S. , and Li, L. 2008. Carotenoid metabolism: Biosynthesis, regulation, and beyond. J. Integr. Plant Biol. 50:778785.

Ma, L. , Zhou, E. , Gao, L. , Mao, X. , Zhou, R. , and Jia, J. 2008. Isolation, expression analysis and chromosomal location of P5CR gene in common wheat (Triticum aestivum L.). S. Afr. J. Bot. 74:705712.

Mahan, J. R. , Gitz, D. C. , Payton, P. R. , and Allen, R. 2009. Overexpression of glutathione reductase in cotton does not alter emergence rates under temperature stress. Crop Sci. 49:272280.

Matsumura, T. , Tabayashi, N. , Kamagata, Y. , Souma, C. , and Saruyama, H. 2002. Wheat catalase expressed in transgenic rice can improve tolerance against low temperature stress. Physiol. Plant 116:317327.

Melchiorre, M. G. , Robert, V. , Trippi, R. , and Racca, H. R. 2009. Lascano, Superoxide dismutase and glutathione reductase overexpression in wheat protoplast: Photooxidative stress tolerance and changes in cellular redox state. Plant Growth Regul. 57:5768.

Michalak, A. 2006. Phenolic compounds and their antioxidant activity in plants growing under heavy metal stress. Polish J. Environ. Stud. 15:523530.

Millar, A. H. , Mittova, V. , Kiddle, G. , et al. 2003. Control of ascorbate synthesis by respiration and its implication for stress responses. Plant Physiol. 133:443447.

Miret, J. A. , and Munn-Bosch, S. 2015. Redox signaling and stress tolerance in plants: A focus on vitamin E. Ann. N.Y. Acad. Sci. 1340:2938.

Mirshad, P. P. , and Puthur, J. T. 2016. Arbuscular mycorrhizal association enhance s drought tolerance potential of promising bioenergy grass (Saccharum arundinaceum retz.). Environ. Monit. Assess. 188:425. doi:10.1007/s10661-016-5428-7.

Miura, K. , and Tada, Y. 2014. Regulation of water, salinity, and cold stress responses by salicylic acid. Front Plant Sci. 5:4. doi:10.3389/fpls.2014.00004.

Mobin, M. and Khan, N. A. 2007. Photosynthetic activity, pigment composition and anti- oxidative response of two mustard (Brassica juncea) cultivars differing in photosynthetic capacity subjected to cadmium stress. J. Plant Physiol. 164:601610.

Mohseni, A. , Nematzadeh, G. A. , Dehestani, A. , Shahin, B. , and Soleimani, E. 2015. Isolation, molecular cloning and expression analysis of Aeluropus littoralis Monodehydroascorbate reductase (MDHAR) gene under salt stress. J. Plant Molec. Breeding 3:7280.

Molinari, H. B. C. , Marur, C. J. , Daros, E. , et al. 2007. Evaluation of the stress-inducible production of proline in transgenic sugarcane (Saccharum spp.): Osmotic adjustment, chlorophyll fluorescence and oxidative stress. Physiol. Plant 130:218229.

Moller, I. M. , Jensen, P. E. and Hansson, A. 2007. Oxidative modications to cellular components in plants. Annu. Rev. Plant Biol. 58:459481.

Mostofa, M. G. , Hossain, M. A. , Fujita, M. , and Tran, L. S. P. 2015. Physiological and biochemical mechanisms associated with trehalose-induced copper-stress tolerance in rice. Sci. Rep. 5:11433. doi:10.1038/srep11433.

Muller-Xing, R. , Xing, Q. , and Goodrich, J. 2014. Footprints of the sun: Memory of UV and light stress in plants. Front. Plant Sci. 5:474. doi:10.3389/fpls.2014.00474.

Munn-Bosch, S. 2005. The role of -tocopherol in plant stress tolerance. J. Plant Physiol. 162:743748.

Munteanu, V. , Gordeev, V. , Martea, R. , and Duca, M. 2014. Effect of gibberellin cross talk with other phytohormones on cellular growth and mitosis to endoreduplication transition. Int. J. Adv. Res. Biol. Sci. 1:136153.

Murphy, M. P. 2009. How mitochondria produce reactive oxygen species. Biochem. J. 417:113.

Nakagami, H. , Kiegerl, S. , and Hirt, H. 2004. OMTK1, a novel MAPKKK, channels oxidative stress signaling through direct MAPK interaction. J. Biol. Chem. 279:2695926966.

Newsholme, P. , Rebelato, E. , Abdulkader, F. , Krause, M. , Carpinelli, A. , and Curi, R. 2012. Reactive oxygen and nitrogen species generation, antioxidant defenses, and -cell function: A critical role for amino acids. J. Endocrinol. 21:411420.

Noctor, G. , Mhamdi, A. , Chaouch, S. , et al. 2011. Glutathione in plants: An integrated overview. Plant Cell Environ. 35:454484.

Nxele, X. , Klein, A. , and Ndimba, B. K. 2017. Drought and salinity stress alters ROS accumulation, water retention, and osmolyte content in sorghum plants. S. Afr. J. Bot. 108:261266.

Pandey, P. , Muthappa, V. , and Senthil-Kumar, M. 2015. Shared and unique responses of plants to multiple individual stresses and stress combinations: Physiological and molecular mechanisms. Front. Plant Sci. 6:723. doi:10.3389/fpls.2015.00723.

Park, A. K. , Kim, I. S. , Do, H. , et al. 2016. Structure and catalytic mechanism of monodehydroascorbate reductase, MDHAR, from Oryza sativa L. Japonica. Sci. Rep. 6:33903. doi:10.1038/srep33903.

Piotrowska-Niczyporuk, A. , Bajguz, A. , Zambrzycka, E. , and Godlewska-ykiewicz, B. 2012. Phytohormones as regulators of heavy metal biosorption and toxicity in green alga Chlorella vulgaris (Chlorophyceae). Plant Physiol. Biochem. 52:5265.

124 Prashanth, S. R. , Sadhasivam, V. , and Parida, A. 2008. Over expression of cytosolic copper/zinc superoxide dismutase from a mangrove plant Avicennia marina in indica rice var Pusa Basmati-1 confers abiotic stress tolerance. Transgenic Res. 17:281291.

Puertas, M. C. R. , Palma, J. M. , Gomez, M. , Rio, L. A. D. and Sandalio, L. M. 2002. Cadmium causes the oxidative modification of proteins in pea plants. Plant Cell Environ. 25:677686.

Racchi, M. L. 2013. Antioxidant defenses in plants with attention to Prunus and Citrus spp. Antioxidants 2:340369.

Raja, V. , Majeeda, U. , Kang, H. , Andrabi, K. I. , and John, R. 2017. Abiotic stress: Interplay between ROS, hormones and MAPKs. Environ. Exp. Bot. 137:142157.

Ramakrishna, A. , and Ravishankar, G. A. 2011. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal. Behav. 6:17201731.

Ramakrishna, A. , and Ravishankar, G. A. 2013. Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In Climate Change and Plant Abiotic Stress Tolerance, ed. N. Tuteja and S. S. Gill, 705 705. Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA.

Ren, J. , Sun, L. N. , Zhang, Q. Y. , Song, X. S. 2016. Drought tolerance is correlated with the activity of antioxidant enzymes in Cerasus humilis seedlings. Biomed. Res. Int. 2016:19.

Rentel, M. C. , Lecourieux, D. , Ouaked, F. , et al. 2004. OXI1 kinase is necessary for oxidative burst-mediated signalling in Arabidopsis. Nature 427:858861.

Rhoads, D. M. , Umbach, A. L. , Subbaiah, C. C. and Siedow, J. N. 2006. Mitochondrial reactive oxygen species contribution to oxidative stress and interorganellar signaling. Plant Physiol. 141:357366.

Rio, L. A. , and Huertas, E. L. 2016. ROS generation in peroxisomes and its role in cell signaling. Plant Cell Physiol. 57:13641376.

Rodriguez, E. S. , Wilhelmi, M. M. R. , Cervilla, L. M. , et al. 2010. Genotypic differences in some physiological parameters symptomatic for oxidative stress under moderate drought in tomato plants. Plant Sci. 178:3040.

Saleh, A. A. H. 2007. Influence of UVA+B radiation and heavy metals on growth, some metabolic activities and antioxidant system in Pea (Pisum sativum) plant. Am. J. Plant Physiol. 2:139154.

Sappl, P. G. , Onate-Sanchez, L. , Singh, K. B. , and Millar, A. H. 2004. Proteomic analysis of glutathione S-transferases of Arabidopsis thaliana reveals differential salicylic acid-induced expression of the plant-specific phi and tau classes. Plant Mol. Biol. 54:205219.

Shackira, A. M. , and Puthur, J. T. 2017. Enhanced phytostabilization of cadmium by a halophyte-Acanthus ilicifolius L. Int. J. Phytoremed. 19:319326.

Shackira, A. M. , Puthur, J. T. , and Salim, N. 2017. Acanthus ilicifolius L. a promising candidate for phytostabilization of zinc. Environ. Monit. Assess. 189:282. doi:10.1007/s10661-017-6001-8.

Sharma. P. , Jha. A. B. , Dubey. R. S. , and Pessarakli. M. 2012. Reactive oxygen species, oxidative damage, and antioxidative defense mechanism in plants under stressful conditions. J. Bot. 2012:126. doi:10.1155/2012/217037.

Simon-Sarkadi, L. , Kocsy, G. , Vrhegyi, . , Galiba, G. , and De Ronde, J. A. 2006. Stress induced changes in the free amino acid composition in transgenic soybean plants having increased proline content. Biol. Plant 50:793796.

Singh, R. , and Jwa, N. S. 2013. Understanding the responses of rice to environmental stress using proteomics. J. Proteome Res. 12:46524669.

Skadsen, R. W. , Schulz-Lefert, P. , and Herbt, J. M. 1995. Molecular cloning, characterization and expression analysis of two classes of catalase isozyme genes in barley. Plant Mol. Biol. 29:10051014.

Smeekens, S. , Ma, J. , Hanson, J. , and Rolland, F. 2010. Sugar signals and molecular networks controlling plant growth. Curr. Opin. Plant Biol. 13:274279.

Sofo, A. , Scopa, A. , Nuzzaci, M. , and Vitti, A. 2015. Ascorbate peroxidase and catalase activities and their genetic regulation in plants subjected to drought and salinity stresses. Int. J. Mol. Sci. 16:1356113578.

Sreenivasulu, N. , Sopory, S. K. , and Kavi-Kishor, P. B. 2007. Deciphering the regulatory mechanisms of abiotic stress tolerance in plants by genomic approaches. Gene 388:113.

Stamm, P. , and Kumar, P. P. 2013. Auxin and gibberellin responsive Arabidopsis SMALL AUXIN UP RNA36 regulates hypocotyls elongation in the light. Plant Cell Rep. 32:759769.

Suzuki, N. , Koussevitzky, S. , Mittler, R. , and Miller, G. 2012. ROS and redox signalling in the response of plants to abiotic stress. Plant Cell Environ. 35:259270.

Sweetlove, L. J. , and Foyer, C. H. 2004. Roles for reactive oxygen species and antioxidants in plant mitochondria. In Plant Mitochondria: From Genome to Function, Advances in Photosynthesis and Respiration, ed. D. A. Day , A. H. Millar , and J. Whelan , 307320. The Netherlands: Kluwer Acad. Press.

Szabados, L. , and Savoure, A. 2009. Proline: A multifunctional amino acid. Trends Plant Sci. 15:8997.

Szechyska-Hebda, M. , Skrzypek, E. , Dbrowska, G. , Biesaga-Kocielniak, J. , Filek, M. , and Wdzony, M. 2007. The role of oxidative stress induced by growth regulators in the regeneration process of wheat. Acta Physiol. Plant 29:327337.

Tth, S. Z. , Nagy, V. , Puthur, J. T. , Kovcs, L. , and Garab, G. 2011. The physiological role of ascorbate as photosystem II electron donor: Protection against photoinactivation in heat-stressed leaves. Plant Physiol. 156:382392.

Turrens, J. F. 2003. Mitochondrial formation of reactive oxygen species. J. Physiol. 552:335344.

Vendruscolo, E. C. G. , Schuster, I. , Pileggi, M. , et al. 2007. Stress-induced synthesis of proline confers tolerance to water deficit in transgenic wheat. J. Plant Physiol. 164:13671376.

Verbruggen, N. , and Hermans, C. 2008. Proline accumulation in plants: A review. Amino Acids 35:753759.

Wang, J. , Zeng, Q. , Zhu, J. , Liu, G. , and Tang, H. 2013. Dissimilarity of ascorbateglutathione (AsAGSH) cycle mechanism in two rice (Oryza sativa L.) cultivars under experimental free-air ozone exposure. Agric. Ecosyst. Environ. 165:3949.

Wang, W. , Vinocur, B. , and Altman, A. 2003. Plant responses to drought, salinity and extreme temperatures: Towards genetic engineering for stress tolerance. Planta 218:114.

Wang, X. , Cai, X. , Xu, C. , Wang, Q. , and Dai, S. 2016a. Drought-responsive mechanisms in plant leaves revealed by proteomics. Int. J. Mol. Sci. 17:17061736.

Wang, X. , Zhang, H. , Gao, Y. , and Zhang, W. 2016b. Characterization of Cu/Zn-SOD enzyme activities and gene expression in soybean under low nitrogen stress. J. Sci. F ood Agric. 96:26922697.

125 Wang, Y. , and Frei, M. 2011. Stressed foodThe impact of abiotic environmental stresses on crop quality. Agric. Ecosyst. Environ. 141:271286.

Wang, Y. , Wisniewski, M. , Meilan, R. , Cui, M. , and Fuchigami, L. 2006. Transgenic tomato (Lycopersicon esculentum) overexpressing cAPX exhibits enhanced tolerance to UV-B and heat stress. J. Appl. Horticult. 8:8790.

Wang, Y. , Wisniewski, M. , Meilan, R. , Cui, M. , Webb, R. , and Fuchigami, L. 2005. Overexpression of cytosolic ascorbate peroxidase in tomato confers tolerance to chilling and salt stress. J. Am. Soc. Hortic. Sci. 130:167173.

Wang, Y. , Ying, Y. , Chen, J. , and Wang, X. C. 2004. Transgenic Arabidopsis overexpressing Mn-SOD enhanced salt-tolerance. Plant Sci. 167:671677.

Wang, Y. C. , Qu, G. Z. , Li, H. Y. , et al. 2010. Enhanced salt tolerance of transgenic poplar plants expressing a manganese superoxide dismutase from Tamarix androssowii. Mol. Biol. Rep. 37:11191124.

Wani, S. H. , Kumar, V. , Shriram, V. , and Sahd, S. K. , 2016. Phytohormones and their metabolic engineering for Abiotic stress tolerance in crop plants. Crop J. 4:162176.

Winger, A. M. , Millar, A. H. , and Day, D. A. 2005. Sensitivity of plant mitochondrial terminal oxidases to the lipid peroxidation product 4-hydroxy-2-nonenal (HNE). Biochem. J. 387:865870.

Woodson, J. D. 2016. Chloroplast quality controlBalancing energy production and stress. New Phytol. 212:3641.

Xu, W. F. , Shi, W. M. , Ueda, A. , and Takabe, T. 2008. Mechanisms of salt tolerance in transgenic Arabidopsis thaliana carrying a peroxisomal ascorbate peroxidase gene from barley. Pedosphere 18:486495.

Yadav, N. and Sharma, S. 2016. Reactive oxygen species, oxidative stress and ROS scavenging system in plants. J. Chem. Pharm. Res. 8:595604.

Yamada, M. , Morishita, H. , Urano, K. , et al. 2005. Effects of free proline accumulation in petunias under drought stress. J. Exp. Bot. 56:19751981.

Yan, J. , Wang, J. , Tissue, D. , Holaday, A. S. , Allen, R. , and Zhang, H. 2003. Photosynthesis and seed production under water-deficit conditions in transgenic tobacco plants that overexpress an arabidopsis ascorbate peroxidase gene. Crop Sci. 43:14771483.

Yan, Z. , Chen, J. , and Li, X. 2013. Methyl jasmonate a s modulator of Cd toxicity in Capsicum frutescens var. fasciculatum seedlings. Ecotoxicol. Environ. Saf. 98:203209.

Yoshimura, K. , Miyao, K. , Gaber, A. , et al. 2004. Enhancement of stress tolerance in transgenic tobacco plants overexpressing Chlamydomonas glutathione peroxidase in chloroplasts or cytosol. Plant J. 37:2133.

You, J. , and Chan, Z. 2015. ROS regulation during abiotic stress responses in crop plants. Front. Plant Sci. 6:1092. doi:10.3389/fpls.2015.01092.

Young, A. J. 1991. The photoprotective role of carotenoids in higher plants. Physiol. Plant 83:702708.

Yu, T. , Li, Y. S. , Chen, X. F. , Hu, J. , Chang, X. , and Zhu, Y. G. 2003. Transgenic tobacco plants overexpressing cotton glutathione S-transferase (GST) show enhanced resistance to methyl viologen. J. Plant Physiol. 160:13051311.

Zagorchev, L. , Seal, C. E. , Kranner, I. , and Odjakova, M. 2013. A central role for thiols in plant tolerance to abiotic stress. Int. J. Mol. Sci. 14:74057432.

Zengin, F. K. , and Munzuroglu, O. 2005. Effects of some heavy metals on content of chlorophyll, proline and some antioxidant chemicals in bean (Phaseolus vulgaris L.) seedlings. Acta Biol. Cracov. Ser. Bot. 47:157164.

Zhang, J. , Jia, W. , Yang, J. , and Ismail, A. M. 2006. Role of ABA in integrating plant responses to drought and salt stresses. Field Crops Res. 97:111119.

Zhou, R. , Yu, X. , Ottosen, C. , et al. 2017. Drought stress had a predominant effect over heat stress on three tomato cultivars subjected to combined stress. BMC Plant Biol. 17:24. doi:10.1186/s12870-017-0974-x.

Zlatev, Z. S. , Lidon, F. C. , Ramalho, J. C. , and Yordanov, I. T. 2006. Comparison of resistance to drought of three bean cultivars. Biol. Plant 50:389394.

Plant Genome Response Related to Phenylpropanoid Induction under Abiotic Stresses

Agati G , Azzarello E , Pollastri S , Tattini M. Flavonoids as antioxidants in plants: Location and functional significance. Plant Science 2012; 196: 6776.

135 Agati G , Brunetti C , Di Ferdinando M , Ferrini F , Pollastri S , Tattini M . Functional roles of flavonoids in photoprotection: New evidence, lessons from the past. Plant Physiology and Biochemistry 2013; 72: 3545.

Ajikumar PK , Xiao WH , Tyo KE , Wang Y , Simeon F , Leonard E , Mucha O , Phon TH , Pfeifer B , Stephanopoulos G. Isoprenoid pathway optimization for taxol precursor overproduction in Escherichia coli. Science 2010; 330: 7074.

Arencibia AD , Bernal A , Yang L , Cortegaza L , Carmona ER , Prez A , Hu C-J , Li Y-R , Zayas CM , Santana I . New role of phenylpropanoid compounds during sugarcane micropropagation in Temporary Immersion Bioreactors (TIBs). Plant Science 2008; 175: 487496.

Arencibia AD , Bernal A , Zayas C , Carmona E , Cordero C , Gonzlez G , Garca R , Santana I. Hydrogen peroxide induced phenylpropanoids pathway eliciting a defensive response in plants micropropagated in Temporary Immersion Bioreactors (TIBs). Plant Science 2012; 195: 7179.

Arencibia AD , Rodriguez C , Roco L , Vergara C , Gonzlez N ; Garca R. Tolerance to heavy metal stress in seedlings of three pine species from contrasting environmental conditions in Chile. IForest-Biogeosciences and Forestry 2016; 9: 937945.

Becker C , Weige D. Epigenetic variation: Origin and transgenerational inheritance. Current Opinion in Plant Biology 2012; 15: 562567.

Bian S , Jiang Y. Reactive oxygen species, antioxidant enzyme activities and gene expression patterns in leaves and roots of Kentucky bluegrass in response to drought stress and recovery. Scientia Horticulturae 2009; 120: 264270.

Boudet A.M. Evolution and current status of research in phenolic compounds. Phytochemistry 2007; 68: 27222735.

Boyko A , Blevins T , Yao Y , Golubov A , Bilichak A , Ilnytskyy Y , Hollander J , Meins FJ , Kovalchuk I. Transgenerational adaptation of Arabidopsis to stress requires DNA methylation and the function of dicer-like proteins. PLoS One 2010; 5(3): e9514. doi:10.1371/journal.pone.0009514.

Boyko A , Kovalchuk I. Genome instability and epigenetic modification heritable responses to environmental stress? Current Opinion in Plant Biology 2011; 14: 260266.

Choudhary M , Jetley UK , Khan MA , Zutsh S , Fatma T. Effect of heavy metal stress on proline, malondialdehyde, and superoxide dismutase activity in the cyanobacterium Spirulina platensis-S5. Ecotoxicology and Environmental Safety 2007; 66: 204209.

Costa MA , Marques JV , Dalisay DS , Herman B , Bedgar DL , Davin LB , Lewis N.G. Transgenic hybrid poplar for sustainable and scalable production of the commodity/specialty chemical, 2-phenylethanol. PLoS One 2013; 8: e83169. doi.org/10.1371/.

Dazy M , Masfaraud J-F , Frard J-F . Induction of oxidative stress biomarkers associated with heavy metal stress in Fontinalis antipyretica Hedw. Chemosphere 2009; 7: 297302.

Deal RB , Henikoff S. Histone variants and modifications in plant gene regulation. Current Opinion in Plant Biology 2011; 14: 116122.

Dias AN , Tarquinio PJ , Eneas FJ , Braga ACE , Gomes F.E. Effect of salt stress on antioxidative enzymes and lipid peroxidation in leaves and roots of salt-tolerant and salt-sensitive maize genotypes. Environmental and Experimental Botany 2006; 56: 8794.

Dias AN , Tarquinio PJ , Eneas FJ , Rolim JVM , Gomes F.E. Hydrogen peroxide pre-treatment induces salt-stress acclimation in maize plants. Journal of Plant Physiology 2005; 162: 11141122.

Daz J , Bernal A , Pomar F , Merino F. Induction of shikimate dehydrogenase and peroxidase in pepper (Capsicum annum L.) seedlings in response to copper stress and its relation to lignification. Plant Science 2001; 161: 179188.

Dong J , Wu F , Zhang G . Influence of cadmium on antioxidant capacity and four microelement concentrations in tomato seedlings (Lycopersicon esculentum). Chemosphere 2006; 64: 16591666.

Dyer AR , Brown CS , Espeland EK , McKay JK , Meimberg H , Rice K.J. The role of adaptive tran s-generational plasticity in biological invasions of plants. Evolutionary Applications 2010; 3: 179192.

Echevarra ZS , Ariza D , Jorge I , Lenz C , Del Campo A , Jorrn JV , Navarro R.M. Changes in the protein profile of Quercus ilex leaves in response to drought stress and recovery. Journal of Plant Physiology 2009; 166: 233245.

Facchini PJ , Bohlmann J , Covello PS , De Luca V , Mahadevan R , Page JE , Ro DK , Sensen CW , Storms R , Martin VJJ . Synthetic biosystems for the production of high-value plant metabolites. Trends in Biotechnology 2012; 30: 127131.

Fini A , Guidi L , Ferrini F , Brunetti C , Di Ferdinando M , Biricolti S , Pollastri S , Calamai L , Tattini M. Drought stress has contrasting effects on antioxidant enzymes activity and phenylpropanoid biosynthesis in Fraxinus ornus leaves: An excess light stress affair? Journal Plant Physiology 2012; 169: 929939.

Gora L , Clijsters H. Effect of copper and zinc on the ethylene metabolism in Phaseolus vulgaris L. In: Clijsters H (ed.). Biochemical and Physiological Aspects of Ethylene Production in Lower and Higher Plants. Kluwer, Dordrecht, 1989, pp. 219228.

Grato PL , Polle A , Lea P.J. , Azevedo R.A. Making the life of heavy metal-stressed plants a little easier. Functional Plant Biology 2005; 32: 481494.

Herman JJ , Sultan S.E. Adaptive transgenerational plasticity in plants: Case studies, mechanisms, and implications for natural populations. Frontiers in Plant Sciences 2011; 27. doi:10.3389/fpls.2011.00102.

Hernndez I , Alegre L , Van Breusegem F , Munn-Bosch S. How relevant are flavonoids as antioxidants in plants? Trends in Plant Sciences 2009; 14: 125132.
Jablonka E , Raz G. Transgenerational epigenetic inheritance: Prevalence, mechanisms, and implications for the study of heredity and evolution. Quarterly Review of Biology 2009; 84: 131176.
Jung C , Maeder V , Funk F , Frey B , Sticher H , Frossard E. Release of phenols from Lupinus albus L. roots exposed to Cu and their possible role in Cu detoxification. Plant Soils 2003; 252: 301312.
Ke Y , Han G , He H , Li J. Differential regulation of proteins and phosphoproteins in rice under drought stress. Biochemical and Biophysical Research Communications 2009; 379: 33138.
Koca H , Bor M , Ozdemi F , Trkan . The effect of salt stress on lipid peroxidation, antioxidative enzymes and proline content of sesame cultivars. Environmental and Experimental Botany 2007; 60: 344351.
Kondo N , Kawashima M. Enhancement of tolerance to oxidative stress in cucumber (Cucumis sativus L.) seedlings by UV-B irradiation: Possible involvement of phenolic compounds and antioxidant enzymes. Journal of Plant Research 2000; 113: 311317.
Kruzmane D , Jankevica L , Ievinsh G. Effect of regurgitant from Leptinotarsa decemlineata on wound responses in Solanum tuberosum and Phaseolus vulgaris. Physiologia Plantarum 2002; 115: 577584.
136 Lavid N , Schwartz A , Yarden O , Telor E. The involvement of polyphenols and peroxidase activities in heavy metal accumulation by epidermal glands of waterlily (Nymphaeceaea). Planta 2001; 212: 323.
Lu D , Yuan X , Kim SJ , Marques JV , Chakravarthy PP , Moinuddin SGA , Luchterhand R , Herman B , Davin LB , Lewis N.G. Eugenol specialty chemical production in transgenic poplar (Populus tremula x P.alba) field trials. Plant Biotechnology Journal 2017; 15: 970981. doi:10.1111/pbi.12692.
Maksymiec W. Signaling responses in plants to heavy metal stress. Acta Physiologia Plantarum 2007; 29: 177187.
Maksymiec W , Krupa Z. Effects of methyl jasmonate and excess copper on root and leaf growth. Biologia Plantarum 2007; 51: 322326.
Masuda T , Inazumi A , Yamada Y , Padolina WG, , Kikuzak H , Nakatani N. Antimicrobial phenylpropanoids from Piper sarmentosum. Phytochemistry 1991; 30: 32273228.
Michalak A. Phenolic compounds and their antioxidant activity in plants growing under heavy metal stress. Polish Journal of Environmental Studies 2006; 15: 523530.
Molinier J , Ries G , Zipfel C , Hohn B. Transgeneration memory of stress in plants. Nature 2006; 442: 10461049.
Nagajyoti PC , Lee KD , Sreekanth T.V.M. Heavy metals, occurrence and toxicity for plants: A review. Environmental Chemical Letters 2010; 8: 199216.
Ozkur O , Ozdemir F , Bor M , Turkan I. Physiochemical and antioxidant responses of the perennial xerophyte Capparis ovata Desf. to drought. Environmental and Experimental Botany 2009; 66: 487492.
Pontin MA , Piccoli PN , Francisco R , Bottini R , Martinez-Zapater JM , Lijavetzky D. Transcriptome changes in grapevine (Vitis viniferaL.) cv. Malbec leaves induced by ultraviolet-B radiation. BMC Plant Biology 2010; 10: 224.
Prasad MNV , Greger M , Landberg T. Acacia nilotica L. bark removes toxic elements from solution: Corroboration from toxicity bioassay using Salix viminalis L. in hydroponic system. International Journal of Phytoremediation 2001; 3: 289300.
Qin W , Huang S , Li C , Chen S , Peng Z. Biological activity of the essential oil from the leaves of Piper sarmentosum Roxb. (Piperaceae) and its chemical constituents on Brontispa longissima (Gestro) (Coleoptera: Hispidae). Pesticide Biochemistry and Physiology 2010; 96: 132139.
Rice-Evans C, Miller N , Paganga G. Antioxidant properties of phenolic compounds. Trends Plant Sciences 1997; 2: 152 152.
Ruiz JM , Rivero RM , Lpez-Cantanero I , Romero L. Role of Ca2+ in metabolism of phenolic compounds in tobacco leaves (Nicotiana tabacum L.). Plant Growth Regulators 2003; 41: 173177.
Rukachaisirikul T , Siriwattanakit P , Sukcharoenphol K , Wongvein C , Ruttanaweang P , Wongwattanavuch P , Suksamrarn A. Chemical constituents and bioactivity of Piper sarmentosum. Journal of Ethnopharmacology 2004; 93: 173176.
Sakihama Y , Yamasaki H. Lipid peroxidation induces by phenolics in cinjunction with aluminium ions. Biologia Plantarum 2002; 45: 249254.
Saniewski M , Ueda J , Miyamoto K , Urbanek H. Interaction between ethylene and other plant hormones in regulation of plant growth and development in natural conditions and under abiotic and biotic stresses. In: Vendrell M , Klee H , Pech JC , Romojaro F (eds.). Biology and Biotechnology of the Plant Hormone Ethylene III. IOS Press, 2003, pp. 263 263.
Schutzendubel A , Polle A. Plant responses to abiotic stresses: Heavy metal induced oxidative stress and protection by mycorrhization. Journal of Experimental Botany 2002; 53: 13511365.
Takahama U , Oniki T. Flavonoid and some other phenolics as substrates of peroxidase: physiological significance of the redox reactions. Journal of Plant Research 2000; 113: 37.
Urano K , Kurihara Y , Seki M , Shinozaki K. Omics analyses of regulatory networks in plant abiotic stress responses. Current Opinion in Plant Biology 2010; 13: 132138.
Vasso DG , Davin LB , Lewis N.G. Metabolic engineering of plant Allyl/propenyl phenol and lignin pathways: Future potential for biofuels/bioenergy, polymer intermediates, and specialty chemicals? Advances in Plant Biochemistry and Molecular Biology 2008; 1: 385428.
Vasso DG , Kim KW , Davin LB , Lewis NG. Lignans (neolignans) and allyl/propenyl phenols: Biogenesis, structural biology, and biological/human health considerations. In: Mander L , Liu HW (eds.). Comprehensive Natural Products II. Chemistry and Biology. Vol. 1: Structural Diversity I. Oxford, UK: Elsevier, 2010, pp. 815928.
Verhoeven KJ , van Gurp T.P. Transgenerational effects of stress exposure on offspring phenotypes in apomictic dandelion. PLOS One 2012; 7: e38605.
Wahid A , Perveen M , Gelani S , Basra S.A. Pretreatment of seed with H2O2 improves salt tolerance of wheat seedlings by alleviation of oxidative damage and expression of stress proteins. Journal of Plant Physiology 2007; 164: 283294.
Winkel-Shirley B. Biosynthesis of flavonoids and effects of stress. Current Opinion Plant Biology 2002; 5: 218223.
Xiao M , Zhanga Y , Chenc X , Leec EJ , Barber C , Chakrabartyc R , Desgagn-Penixc I , et al. Transcriptome analysis based on next-generation sequencing of non-model plants producing specialized metabolites of biotechnological interest. Journal of Biotechnology 2013; 166: 122134.
Yamaguchi SK , Shinozaki K. Transcriptional regulatory networks in cellular responses and tolerance to dehydration and cold stresses. Annual Review Plant Biology 2006; 57: 781803.
Yang L , Zambrano Y , Hu C-J , Carmona ER , Bernal A , Prez A , Li Y-R ; Guerra A , Santana I , Arencibia AD . Sugarcane metabolites produced in CO2-rich Temporary Immersion Bioreactors (TIBs) induce tomato (Solanum lycopersicum) resistance against bacterial wilt (Ralstonia solanacearum). In Vitro Cell Development-Plan 2010; 46: 558568.
Zakaria ZA , Patahuddin H , Mohamad AS , Israf DA , Sulaiman MR . In vivo anti-nociceptive and anti-inflammatory activities of the aqueous extract of the leaves of Piper sarmentosum. Journal of Ethnopharmacology 2010; 128: 4248.
Zhang F , Wang YS , Lou ZP , Dong J.D. Effect of heavy metal stress on antioxidative enzymes and lipid peroxidation in leaves and roots of two mangrove plant seedlings (Kandelia candel and Bruguiera gymnorrhiza). Chemosphere 2007; 67: 4450.

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Arman M , Gholipour A. Seed morphology diversity in some Iran endemic silene (Caryophyllaceae) species and their taxonomic significance. Acta Biol. Szegediensis 2013; 57(1): 3137.

Ayyad MA , Ghabbour S.I. Hot deserts of Egypt and Sudan. In: Ecosystems of the World (M. Evenari , Y. Noy-Meir , and D. W. Godall , eds.). Elsevier, Amsterdam, 1986; vol. 12 B, 149202.

Barrco RM , Van Poucke K , Bergervoet JH , De Veylder L , Groot SP , Inz D , Engler G. The role of the cell cycle machinery in resumption of postembryonic development. Plant Physiol. 2005; 137(1): 127140.

Baskin CC , Baskin J.M. Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination. Academic Press, San Diego, 2001.

Bayrakdar F , Ayta Z , Suludere Z , Candan S. Seed morphology of Ebenus L. species endemic to Turkey. Turk J. Bot. 2010; 34: 283289.

Beaudoin N , Serizet C , Gosti F , Giraudat J. Interactions between abscisic acid and ethylene signaling cascades. Plant Cell 2000; 12(7): 11031115.

Begon M , Townsend CA , Harper J.L. Ecology: From Individuals to Ecosystems. 4th ed. Blackwell, Maldon, MA, 2006.

Bentsink L , Koornneef M. Seed dormancy and germination. Arabidopsis Book 2008; 6: e0119. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3243337/

Cervantes E. Challenging arabidopsis thaliana as the ultimate model species: Can seed germination be the achiles heel? Eur. J. Plant Sci. Biotechnol. 2008; 2(1): 106109.

Cervantes E , Martin JJ , Ardanuy R , de Diego JG , Tocino A. Modeling the Arabidopsis seed shape by a cardioid: Efficacy of the adjustment with a scale change with factor equal to the Golden Ratio and analysis of seed shape in ethylene mutants. J. Plant Physiol. 2010; 167: 408410. doi:10.1016/j.jplph.2009.09.013.

Cervantes E , Martin JJ , de Diego JG , Chan PK , Gresshoff P , Tocino A. Seed shape in model legumes: Approximation by a cardioid reveals differences between Lotus and Medicago. J. Plant Physiol. 2012; 169(14): 13591365. doi:10.1016/j.jplph.2012.05.019.

Cervantes E , Martn Gmez JJ , Saadaoui, E. Updated methods for seed shape analysis. Scientifica (Hyndawi) 2016. doi:10.1155/2016/5691825.

146 de Diego JG , David Rodrguez F , Rodrguez Lorenzo JL , Cervantes E. The prohibitin genes in Arabidopsis thaliana: Expression in seeds, hormonal regulation and possible role in cell cycle control during seed germination. J. Plant Physiol. 2007; 164(3): 371373.

El Nagar SM , Soliman M.A. Biosystematic studies on Schouwia DC. (Brassicaceae) in Egypt. Flora Mediterr. 1999; 9: 175183.

FAO (Food and Agriculture Organization). Arid Zone Forestry: A Guide for Field Technicians. Publications Division, Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, Rome, Italy, 1989.

Gamoun M , Hanchi B , Neffati M. Dynamic of plant communities in Saharan rangelands of Tunisia. Arid Ecosyst. 2012; 2: 105110.

Ghassemian M , Nambara E , Cutler S , Kawaide H , Kamiya Y , McCourt P. Regulation of abscisic acid signaling by the ethylene response pathway in Arabidopsis. Plant Cell 2000; 12(7): 11171126.

Gibson SI , Laby RJ , Kim D . The sugar-insensitive1 (sis1) mutant of Arabidopsis is allelic to ctr1. Biochem. Biophys. Res. Commun. 2001; 280(1): 196203.

Gorai M , El Aloui W , Yang X , Neffati M. Toward understanding the ecological role of mucilage in seed germination of a desert shrub Henophytondeserti: Interactive effects of temperature, salinity and osmotic stress. Plant Soil 2014; 374: 727738.

Hall JC , Sytsma KJ , Iltis H.H. Phylogeny of Capparaceae and Brassicaceae based on chloroplast sequence data. Am. J. Bot. 2002; 89(11): 18261842.

Hannachi H , Martn JJ , Saadaoui E , Cervantes E. Stone diversity in wild and cultivated olive trees (Olea europaea L.). Dendrobiology 2017; 77: 1932.

Hassan, NMS , Meve U , Liede-Schumann S. Seed coat morphology of AizoaceaeSesuvioideae, Gisekiaceae and Molluginaceae and its systematic significance. Bot. J. Linnean Soc. 2005; 148: 189206.

Holdsworth MJ , Finch-Savage WE , Grappin P , Job D. Post-genomics dissection of seed dormancy and germination. Trends Plant Sci 2008; 13(1): 713.

Hourou H.N. Bioclimatology and Biogeography of Africa. Springer Verlag, Berlin. 2008; ISBN 978-3-540-85192-9.

Huang Z , Liu S , Bradford KJ , Huxman TE , Venable D.L. The contribution of germination functional traits to population dynamics of a desert plant community. Ecology 2016; 97: 250261.

Lioubimtseva E. Climate change in arid environments: Revisiting the past to understand the future. Prog. Phys. Geogr. 2004; 28(4): 502530.

Liu PP , Montgomery TA , Fahlgren N , Kasschau KD , Nonogaki H , Carrington J.C. Repression of AUXIN RESPONSE FACTOR10 by microRNA160 is critical for seed germination and post-germination stages. Plant J. 2007; 52(1): 133146.

Mahdavi M , Assadi M , Fallahian F , Nejadsattari T. The systematic significance of seed micro-morphology in Stellaria L. (Caryophyllaceae) and its closes relatives in Iran. Iran. J. Bot. 2012; 18(2): 302310.

Martn Gmez JJ , Saadaoui E , Cervantes E. Climatic effects in seed shape of castor bean (Ricinus communis L.) grown in Tunisia. J. Agric. Ecol. Res. Int. 2016a; 8(1): 111. doi:10.9734/JAERI/2016/23934.

Martn JJ , Saadaoui E , Cervantes E. Seed shape quantification in Capparis spinosa L.: Effect of subspecies and geographic regions. SCIREA J. Agric. 2016b; 1(1): 7990.

Martn JJ , Tocino A , Ardanuy R , de Diego JG , Cervantes E. Dynamic analysis of Arabidopsis seed shape reveals differences in cellulose mutants. Acta Physiol Plant. 2014; 36: 15851592.

Martnez-Berdeja A. Rainfall variability in deserts and the timing of seed release in chorizanthe rigida a serotinous winter desert annual. Thesis in Biology. University of California, Riverside, CA, 2014.

Mittler R , Merquiol E , Hallak-Herr E , Rachmilevitch S , Kaplan A , Cohen M. Living under a dormant canopy: A molecular acclimation mechanism of the desert plant Retama raetam. Plant J. 2001; 25(4): 407416.

Mtimet A. Soils of Tunisia. In: Soil Resources of Southern and Eastern Mediterranean Countries (P. Zdruli , P. Steduto , C. Lacirignola , and L. Montanarell a , eds.). Options Mditerranennes: Srie B. Etudes et Recherches; n. 34. Bari: CIHEAM, 2001, 243262.

Mulas M , Mulas G. The strategic use of Atriplex and Opuntia to combat desertification. University of Sassari, Italy, 2004.

Peco B , Traba J , Levassor C , Snchez AM , Azcrate E.M. Seed size, shape and persistence in dry Mediterranean grass and scrublands. Seed Sci. Res. 2003; 13: 8795.

Rajjou L , Gallardo K , Debeaujon I , Vandekerckhove J , Job C , Job D. The effect of alpha-amanitin on the Arabidopsis seed proteome highlights the distinct roles of stored and neosynthesized mRNAs during germination. Plant Physiol. 2004; 134(4): 15981613.

Rodrguez JL , De Diego JG , Rodrguez FD , Cervantes E. Mitochondrial structures during seed germination and early seedling development in Arabidopsis thaliana. Biologia 2015; 70(8): 10191025.

Saadaoui E , Guetat A , Massoudi Ch , Tlili N , Khaldi A. Wild Tunisian Capparis spinosa L.: Subspecies and seed fatty acids. Int. J. Curr. Res. Acta. Rev. 2015; 3(1): 315327.

Saadaoui E , Guetat A , Tlili N , El Gazzah M , Khaldi A. Subspecific variability of Tunisian wild populations of Capparis spinosa L. J. Med. Plants Res. 2011; 5(17): 43394348.
Saadaoui E , Martn Gmez JJ , Cervantes E. Intraspecific variability of seed morphology in Capparis spinosa L. Acta Biol. Cracovensia (Sect Botanica) 2013; 55: 18. doi:10.2478/abcsb-2013-0027.
Saadaoui E , Martn Gmez JJ , Cervantes E. Effect of climate in seed diversity of wild Tunisian Rhus tripartita (Ucria) Grande. J. Adv. Biol. Biotechnol. 2017a; 13(4): 110.
Saadaoui E , Martn Gmez JJ , Ghazel N , Ben Yahia K , Tlili N , Cervantes, E. Genetic variation and seed yield in Tunisian castor bean (Ricinus communis L.) Bot. Sci. 2017b; 95(2): 271281.
Saadaoui E , Martin Gmez JJ , Kaouther ben Yahia K , Cervantes E. Seed morphology and germination in spontaneous and cultivated populations of Nerium oleander var. Villa Romaine grown in Tunisia, submitted.
Tantawy ME , Khalifa SF , Hassan SA , Al-Rabiai, G.T. Seed Exomorphic Characters of Some Brassicaceae (LM and SEM Study). Int. J. Agri. Biol. 2004; 6(5): 821830.
Tlili N , Saadaoui E , Sakouhi F , Elfalleh W , El Gazzah M , Triki S , Khaldi A. Morphology and chemical composition of Tunisian caper seeds: Variability and population profiling. Afr. J. Biotechnol. 2011; 10(10): 21122118.
You H , Jin H , Khaldi A , Kwak M , Lee T , Khaine I , Jang J , et al. Plant diversity in different bioclimatic zones in Tunisia. J. Asia-Pac. Biodivers. 2016; 9(1): 5662.
Zhou L , Jang JC , Jones TL , Sheen J. Glucose and ethylene signal transduction crosstalk revealed by an Arabidopsis glucose-insensitive mutant. Proc. Natl. Acad. Sci. USA. 1998; 956(1): 1029410299.

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Bez, A. , Belmont, R. , Garca, R.M. , Padilla, H. , and Torres, M.C. 2007. Chemical composition of rainwater collected at a southwest site of Mexico City, Mexico. Rev. Atmos. Res. 86: 6175.
Barandovski, L. , Cekova, M. , Frontasyeva, M.V. , Pavlov, S.S. , Stafilov, T. , Steinnes, E. , and Urumov, V. 2008. Atmospheric deposition of trace element pollutants in Macedonia studied by the moss biomonitoring technique. Environ. Monit. Assess. 138: 107118. doi:10.1007/s10661-007-9747-6.
Baxter, I. 2009. Ionomics: Studying the social network of mineral nutrients. Curr. Opin. Plant Biol. 12: 381386.
Baxter, I. , Brazelton, J.N. , Yu, D. , Huang, Y.S. , Lahner, B. , Yakubova, E. , Li, Y. , et al. 2010. A coastal cine in sodium accumulation in Arabidopsis thaliana is driven by natural variation of the sodium transporter AtHKT1;1. PLoS Genet. 6: e1001193.
Baxter, I. , Christian, H. , Lahner, B. , Elena, Y. , Tikhonova, M. , Verbruggen, N. , Chao, D. , and Salt, D.E. 2012. Biodiversity of mineral nutrient and trace element accumulation in Arab idopsis thaliana. PLoS ONE 7(4): e35121.
Baxter, I. , Ouzzani, M. , Orcun, S. , Kennedy, B. , Jandhyala, S.S. , and Salt, D.E. 2007. Purdue ionomics information management system. An integrated functional genomics platform. Plant Physiol. 143(2): 600611.
Baxter, I.R. , Vitek, O. , Lahner, B. , Muthukumar, B. , Borghi, B. , Morrissey, J. , Lou Guerinot, M.L. , and Salt, D.E. 2008. The leaf ionome as a multivariable system to detect a plants physiological status. Proc. Natl. Acad. Sci. USA 105(33): 1208112086.
Becher, M. , Talke, I.N. , Krall, L. , and Kramer, U. 2004. Cross-species microarray transcript profiling reveals high constitutive expression of metal homeostasis genes in shoots of the zinc hyperaccumulator Arabidopsis halleri. Plant J. 73: 251268.
Broadley, M.R. , Hammond, J.P. , White, P.J. and Salt, D.E. 2010. An efficient procedure for normalizing ionomics data for Arabidopsis thaliana. New Phytol. 186: 270274.
Chen, Z. , Shinano, T. , Ezawa, T. , Wasaki, J. , Kimura, K. , Osaki, M. and Zhu, Y. 2009. Elemental interconnections in Lotus japonicus: A systematic study of the effects of elements additions on different natural variants. Soil Sci. Plant Nutr. 55(1): 91101.
Curie, C. , and Briat, J.F. 2003. Iron transport and signaling in plants. Annu. Rev. Plant Biol. 54: 183206.
Debnath, M. , Lal, P. , and Jain, R. 2015. Inductively coupled plasma-mass spectrometric profiling of metal contamination in Holi colours. Curr. Sci. 108(8): 14241427.
Delhaize, E. , and Randall, P.J. 1995. Characterization of a phosphate-accumulator mutant of Arabidopsis thaliana. Plant Physiol. 107: 207213.
Delhaize, E. , Randall, P.J. , Wallace, P.A. , and Pinkerton, A. 1993. Screening Arabidopsis for mutants in mineral nutrition. Plant Soil 155/156: 131134.
Fiehn, O. , Kopka, J. , Dormann, P. , Altmann, T. , Trethewey, R.N. , and Willmitzer, L. 2000. Metabolite profiling for plant functional genomics. Nat. Biotech. 8: 11571161.
Garca, R. , Belmont, R. , Padilla, H. , Torres, M.C. , and Bez, A. 2009. Trace metals and inorganic ion measurements in rain from Mexico City and a nearby rural area. Rev. Chem. Ecol. 25(2): 7186.
Glocker, R. , and Schreiber, H. 1928. Quantitative rntgenspektralanalyse mit kalterregung des spektrums. Ann. Physik. 85: 1089.
Gojon, A. , Philippe, N. , and Davidian, J.C. 2009. Root uptake regulation: A central process for NPS homeostasis in plants. Curr. Opin. Plant Biol. 12(3): 328338.
Hirschi, K.D. 2003. Striking while the ionome is hot: Making the most of plant genomic advances. Trends Biotechnol. 21: 520521.
Induri, B.R. , Ellis, D.R. , Slavov, G.T. , Yin, T. , Zhang, X. , Muchero, W. , Tuskan, G.A. , and DiFazio, S.P. 2012. Identification of quantitative trait loci and candidate genes for cadmium tolerance in Populus. Tree Physiol. 32(5): 626638.
Karley, A.J. , and Philip, J.W. 2009. Moving cationic minerals to edible tissues: Potassium, magnesium, calcium. Curr. Opin. Plant Biol. 12(3): 291298.
Koike, S. , Inoue, H. , Mizuno, D. , Takahashi, M. , Nakanishi, H. , Mori, S. , and Nishizawa, N.K. 2004. OsYSL2 is a rice metal-nicotianamine transporter that is regulated by iron and expressed in the phloem. Plant J. 39: 415424.
Koller, A. , Washburn, M.P. , Lange, B.M. , Andon, N.L. , Deciu, C. , and Haynes, P.A. 2002. Proteomic survey of metabolic pathways in rice. Proc. Natl. Acad. Sci. USA 99: 1196911974.
Kramer, U. , Cotter-Howells, J.D. , Charnock, J.M. , Baker, A.J.M. , and Smith, J.A.C. 1996. Free histidine as a metal chelator in plants that accumulate nickel. Nature 379: 635638.
Lahner, B. , Gong, J. , Mahmoudian, M. , Smith, E.L. , Abid, K.B. , Rogers, E.E. , Guerinot, M.L. , Harper, J.F. , Ward, J.M. , and McIntyre, L. 2003. Genomic scale profiling of nutrient and trace elements in Arabidopsis thaliana. Nat. Biotech. 21: 12151221.
154 Leonhardt, N. , Kwak, J.M. , Robert, N. , Waner, D. , Leonhardt, G. , and Schroeder, J.I. 2004. Microarray expression analysis of Arabidopsis guard cells and isolation of a recessive abscisic acid hypersensitive protein phosphatase 2C mutant. Plant Cell 16: 596615.
Luan, S. , Wenzhilan, S. , and Chul, L. 2009. Potassium nutrition, sodium toxicity, and calcium signaling: Connections through the CBL-CIPK network. Curr. Opin. Plant Biol. 12(3): 339346.
Maathuis, F.J. , Filatov, V. , Herzyk, P. , Krijger, G.C. , Axelsen, K.B. , Chen, S. , Green, B.J. , Li, Y. , Madagan, K.L. , and Sanchez-Fernandez, R. 2003. Transcriptome analysis of root transporters reveals participation of multiple gene families in the response to cation

stress. Plant J. 35: 675692.
Marschner, H. 1995. Mineral Nutrition of Higher Plants. 2nd edn. London: Academic Press.
Martin, C. , Kiran, B. , and Kim, B. 2001. Shaping in plant cells. Curr. Opin. Plant Biol. 4(6): 540549.
Martzivanou, M. , and Hampp, R. 2003. Hyper-gravity effects on the Arabidopsis transcriptome. Physiol. Plant 118: 221231.
Maser, P. , Thomine, S. , Schroeder, J.I. , Ward, J.M. , Hirschi, K. , Sze, H. , Talke, I.N. , Amtmann, A. , Maathuis, F.J.M. , and Sanders, D. 2001. Phylogenetic relationships within cation-transporter families of Arabidopsis thaliana. Plant Physiol. 126: 16461667.
Narayanan, N. , Narayanan, M.W. , Vasconcelos, M. , and Grusk, A. 2007. Expression profiling of Oryza sativa metal homeostasis genes in different rice cultivars using a cDNA macroarray. Plant Physiol. Biochem. 45(5): 277286.
Negishi, T. , Nakanishi, H. , Yazaki, J. , Koshimoto, N. , Fujii, F. , Shimbo, K. , Yamamoto, K. , Sakata, K. , Sasaki, T. , and Kikuchi, S. 2002. cDNA microarray analysis of gene expression during Fe-deficiency stress in barley suggests that polar transport of vesicles is implicated in phytosiderophore secretion in Fe-deficient barley roots. Plant J. 30: 8394.
Norton, G.J. , Deacon, C.M. , Xiong, L. , Huang, S. , Meharg, A.A. , and Price, A.H. 2010. Genetic mapping of the rice ionome in leaves and grain: Identification of QTLs for 17 elements including arsenic, cadmium, iron and selenium. Plant Soil 329: 139153.
Nublat, A. , Desplans, J. , Casse, F. , and Berthomieu, P. 2001. sas1, an Arabidopsis mutant overaccumulating sodium in the shoot, shows deficiency in the control of the root radial transport of sodium. Plant Cell 13: 125137.
Pickering, I.J. , Gumaelius, L. , Harris, H.H. , Prince, R.C. , Hirsch, G. , Banks, J.A. , Salt, D.E. , and George, G.N. 2006. Localizing the biochemical transformations of arsenate in a hyperaccumulating fern. Environ. Sci. Technol. 40: 50105014.
Pilon, M. , Christopher, M.C. , Karl, R. , Salah E. Abdel-Ghany , and Frederic, G. 2009. Essential transition metal homeostasis in plants. Curr. Opin. Plant Biol. 12(3): 347357.
Puig, S. , and Penarrubia, L. 2009. Placing metal micronutrients in context: Transport and distribution in plants. Curr. Opin. Plant Biol. 12(3): 299306.
Punshon, T. , Guerinot, M.L. , and Lanzirotti, A. 2009. Using synchrotron X-ray fluorescence microprobes in the study of metal homeostasis in plants. Ann. Bot. 103: 665672.
Punshon, T. , Jackson, B.P. , Bertsch, P.M. , and Burger, J. 2004. Mass loading of nickel and uranium on plant surfaces: Application of laser ablation-ICP-MS. J. Environ. Monit. 6: 153159.
Punshon, T. , Ricachenevsky, F.K. , Hindt, M. , Socha, A.L. , and Zuber, H. 2013. Methodological approaches for using synchrotron X-ray fluorescence (SXRF) imaging as a tool in ionomics: Examples from Arabidopsis thaliana. Metallomics 5(9): 11331145. doi:10.1039/c3mt00120b.
Ramesh, S.A. , Shin, R. , Eide, D.J. , and Schachtman, D.P. 2003. Differential metal selectivity and gene expression of two zinc transporters from rice. Plant Physiol. 133: 126134.
Rausch, C. , and Bucher, M. 2002. Molecular mechanisms of phosphate transport in plants. Planta 216: 2337.
Rea, P.A. 2003. Ion genomics. Nat. Biotech. 21: 11491151.
Salt, D.E. , Prince, R.C. , Pickering, I.J. , and Raskin, I. 1995. Mechanisms of cadmium mobility and accumulation in Indian mustard. Plant Physiol. 109: 14271433.
Sammut, M.L. , Noack, Y. , Rose, J. , Hazemann, J.L. , Proux, O. , Depoux, M. , Ziebel, A. , and Fiani, E. 2010. Speciation of Cd and Pb in dust emitted from sinter plant. Chemosphere 78: 445.
Sanders, D. , Pelloux, J. , Brownless, C. , and Harper, J.F. 2002. Calcium at the crossroads of signaling. Plant Cell 14: S410S417.
Singh, U.M. , Sareen, P. , Sengar, R.S. , and Kumar, A. 2013. Plant ionomics: A newer approach to study mineral transport and its regulation. Acta Physiol. Plant. 35: 26412653.
Sperotto, R.A. , Tatiana, B. , Guilherme, L. , Duarte, L.S. , Santos, M. , Grusak, A. , and Janette P.F. 2010. Identication of putative target genes to manipulate Fe and Zn concentrations in rice grains. J. Plant Physiol. 167: 15001506.
Tejada-Jimenez, M. , Galvan, A. , Fernandez, E. , and Llamas, A. 2009. Homeostasis of the micronutrients Ni, Mo and Cl with specific biochemical functions. Curr. Opin. Plant Biol. 12: 358363.
Vermani, A. , Navneet, P. , and Chauhan, A. 2010. Physico-chemical analysis of ash of some medicinal plants growing in Uttarakhand. India. Nat. Sci. 8 (6): 8891.
Very, A.A. , and Sentenac, H. 2003. Molecular mechanisms and regulation of K+ transport in higher plants. Annu. Rev. Plant Biol. 54: 575603.
Wang, R. , Okamoto, M. , Xing, X. , and Crawford, N.M. 2003. Microarray analysis of the nitrate response in Arabidopsis roots and shoots reveals over 1,000 rapidly responding genes and new linkages to glucose, trehalose-6-phosphate, iron, and sulfate metabolism. Plant Physiol. 132: 556567.
Watanabe, T. , Broadley, M.R. , and Jansen, S. 2007. Evolutionary control of leaf element composition in plants. New Phytol. 174: 516523.
White, P.J. , and Broadley, M.R. 2009. Biofortification of crops with seven mineral elements often lacking in human diets-iron, zinc, copper, calcium, magnesium, selenium and iodine. New Phytol. 182: 4984.
White, P.J. , Broadley, M.R. , Thompson, J.A. , McNicol, J.W. , Crawley, M.J. , Poulton, P.R. , and Johnston, A.E. 2012. Testing the distinctness of shoot ionomes of angiosperm families using the Rothamsted Park Grass Continuous Hay experiment. New Phytol. 196(1): 101109.
Zhao, Fang-J. , Katie, L. , Moore, L.E. , and Zhu, Y.G. , Imaging element distribution and speciation in plant cells. Trends Plant Sci. 19(3): 183192.
Zhu, J.K. 2003. Regulation of ion homeostasis under salt stress. Curr. Opin. Plant Biol. 6: 441445.

Role of Glutamate-Derived Amino Acids under Stress Conditions: The Case of Glutamine and Proline

Abraham E , Rigo G , Szkely G , Nagy R , Koncz C , Szabados L. Light-dependent induction of proline biosynthesis by abscisic acid and salt stress is inhibited by brassinosteroid in Arabidopsis. Plant Mol. Biol. 2003; 51: 363372.
165 Ahmad I , Wainwright SJ , Stewart G.R. The solute and water relations of Agrostis stolonifera ecotypes differing in their salt tolerance. New Phytol. 1981; 87: 615629.
Alia A, Mohanty P , Matysik J. Effect of proline on the production of singlet oxygen. Amino Acids 2001; 21: 195200.
Ashraf M , Foolad M.R. Roles of glycinebetaine and proline in improving plant abiotic stress tolerance. Environ. Exp. Bot. 2007; 59: 206216.
Atkinson D.E. Cellular Energy Metabolism and Its Regulation. New York: Academic Press, 1977.
Bauer D , Biehler K , Fock H , Carrayol E , Migge A , Becker T.W. A role for cytosolic glutamine synthetase in the remobilization of leaf nitrogen during water stress. Physiol. Plant. 1997; 99: 241248.

Bernard SM , Habash D. The importance of cytosolic glutamine synthetase in nitrogen assimilation and recycling. New Phytol. 2009; 182: 608620.
Berteli F , Corrales E , Guerrero C , Ariza MJ , Pilego F , Valpuesta V. Salt stress increases ferredoxin-dependent glutamate synthase activity and protein level in the leaves of tomato. Physiol. Plant. 1995; 93: 259264.
Bhaskara GB , Nguyen TT , Verslues P.E. Unique drought resistance functions of the Highly ABA-Induced clade A protein phosphatase 2Cs. Plant Physiol. 2012; 160: 379395.
Bhaskara GB , Yang TH , Verslues P. Dynamic proline metabolism: Importance and regulation in water limited environments. Front. Plant Sci. 2015; 6: 484.
Biancucci M , Mattioli R , Forlani G , Funck D , Costantino P , Trovato M. Role of proline and GABA in sexual reproduction of angiosperms. Front. Plant Sci. 2015; 6: 680.
Blum, A. Drought resistance, water-use efficiency, and yield potentialAre they compatible, dissonant, or mutually exclusive? Aust. J. Agric. Res. 2005; 56. 11591168.
Borsani O , Daz P , Monza J. Proline is involved in water stress responses of Lotus corniculatus nitrogen fixing and nitrate fed plants. J. Plant Physiol. 1999; 155: 269273.
Borsani O , Zhu J , Verslues PE , Sunkar R , Zhu J.K. Endogenous siRNAs derived from a pair of natural cis-antisense transcripts regulate salt tolerance in Arabidopsis. Cell 2005; 123: 12791291.
Bousba R , Baum M , Jighly A , Djekoune A , Lababidi S , Benbelkacem A , Labhilili M , Gaboun F , Ykhlef N. Association analysis of ge notypic and phenotypic traits using SSR marker in durum wheat. Online Int. Interdiscip. Res. J. 2013; III: 6079.
Brown LM , Hellebust J.A. Sorbitol and proline as intracellular osmotic solutes in the green alga Stichococcus bacillaris. Can. J. Bot. 1978; 56: 676679.
Brugire N , Dubois F , Limami AM , Lelandais M , Roux Y , Sangwan RS , Hirel B. Glutamine synthetase in the phloem plays a major role in controlling proline production. Plant Cell 1999; 11: 19952011.
Burton R.S. Regulation of proline synthesis in osmotic response: Effects of protein synthesis inhibitors. J. Exp. Zool. 1991; 259: 272277.
Bssis D , Heineke D. Acclimation of potato plants to polyethylene glycol-induced water deficit. J. Exp. Bot. 1998; 49: 13611370.
Cammaerts D , Jacobs M. A study of the role of glutamate dehydrogenase in the nitrogen metabolism of Arabidopsis thaliana. Planta 1985; 163: 517526.
Chen Z , Cuin TA , Zhou M , Twomey A , Naidu BP , Shabala S. Compatible solute accumulation and stress-mitigating effects in barley genotypes contrasting in their salt tolerance. J. Exp. Bot. 2007; 58: 42454255.
Cheynier V , Comte G , Davies KM , Lattanzio V , Martens S. Plant phenolics: recent advances on their biosynthesis, genetics, and ecophysiology. Plant Physiol. Biochem. 2013; 72: 120.
Chiang HH , Dandekar A.M. Regulation of proline accumulation in Arabidopsis during development and in response to desiccation. Plant Cell Environ. 1995; 18: 12801290.
Corpas FJ , Barroso J.B. Nitro-oxidative stress vs oxidative or nitrosative stress in higher plants. New Phytol. 2013; 199: 633635.
Coruzzi G.M. Primary N-assimilation into Amino Acids in Arabidopsis. The Arabidopsis Book 2003; 2: e0010.
Cramer MD , Gao ZF , Lips S.H. The influence of dissolved inorganic carbon in the rhizosphere on carbon and nitrogen metabolism in salinity-treated tomato plants. New Phytol. 1999; 142: 441453.
Csonka L.N. Physiological and genetic responses of bacteria to osmotic stress. Microbiol. Rev. 1989; 53: 121147.
Csonka LN , Gelvin SB , Goodner BW , Orser CS , Siemieniak D , Slightom J.L. Nucleotide sequence of a mutation in the proB gene of Escherichia coli that confers proline overproduction and enhanced tolerance to osmotic stress. Gene 1988; 64: 199205.
da Rocha IM , Vitorello VA , Silva JS , Ferreira-Silva Sl , Vigas RA , Silva EN , Sileira J.A. Exogenous ornithine is an effective precursor and the -ornithine amino transferase pathway contributes to proline accumulation under high N recycling in salt-stressed cashew leaves. J. Plant Physiol. 2012; 169: 4149.
Dandekar AM , Uratsu S.L. A single base pair change in proline biosynthesis genes causes osmotic stress tolerance. J. Bacteriol. 1988; 170: 59435945.
Delauney AJ , Verma D.P.S. A soybean gene encoding 1-pyrroline-5-carboxylate reductase was isolated by functional complementation in Escherichia coli and is found to be osmoregulated. Mol. Gen. Genet. 1990; 221: 299305.
Daz P , Borsani O , Mrquez A , Monza J. Osmotically induced proline accumulation in Lotus corniculatus leaves is affected by light and nitrogen source. Plant Growth Regul. 2005; 46: 223232.
El-khatib RT , Hamerlynck E , Gallardo F , Kirby E. Transgenic poplar characterized by ectopic expression of a pine cytosolic glutamine synthetase gene exhibits enhanced tolerance to water stress. Tree Physiol. 2004; 24: 729736.
Fan Y , Shabala S , Ma Y , Xu R , Zhou M. Using QTL mapping to investigate the relationships between abiotic stress tolerance (drought and salinity) and agronomic and physiological traits. BMC Genom. 2015; 16: 43.
Floyd RA , Nagy Z.S. Formation of long-lived hydroxyl free radical adducts of proline and hydroxyproline in a Fenton reaction. Biochem. Biophys. Acta 1984; 790: 9497.
Fuentes SI , Allen DJ , Ortiz-Lopez A , and Hernndez G. Over-expression of cytosolic glutamine synthetase increases photosynthesis and growth at low nitrogen concentrations. J. Exp. Bot. 2001; 52: 10711081.
Funayama K , Kojima S , Tabuchi-Kobayashi M , Sawa Y , Nakayama Y , Hayakawa T , Yamaya T. Cytosolic glutamine synthetase1;2 is responsible for the primary assimilation of ammonium in rice roots. Plant Cell Physiol. 2013; 54: 934943.
Funck D , Eckar S , Mller G. R Non-redundant functions of two proline dehydrogenase isoforms in Arabidopsis. BMC Plant Biol. 2010; 10: 70.
Funck D , Stadelhofer B , Koch W. Ornithine--aminotransferase is essential for arginine catabolism but not for proline biosynthesis. BMC Plant Biol. 2008; 8: 40.
166 Funck D , Winter G , Baumgarten L , Forlani G. Requirement of proline synthesis during Arabidopsis reproductive development. BMC Plant Biol. 2012; 12: 191.
Gallais A , Hirel B. An approach to the genetics of nitrogen use efficiency in maize. J. Exp. Bot. 2004; 55: 295306.
Gallardo F , Fu J , Cantn FR , Garca-Gutirrez A , Cnovas FM , Kirby E.G. Expression of a conifer glutamine synthetase gene in transgenic poplar. Planta 1999; 210: 1926.
Garca-Caldern M , Pons-Ferrer T , Mrzova A , Palove-Balang P , Vilkov M , Prez-Delgado CM , Vega JM , Eliov A , Repk M , Mrquez AJ , Betti M. Modulation of phenolic metabolism under stress conditions in a Lotus japonicus mutant lacking plastidic glutamine synthetase. Front. Plant Sci. 2015; 6: 760.
Giberti S , Funck D , Forlani G. 1-pyrroline-5-carboxylate reductase from Arabidopsis thaliana: stimulation or inhibition by chloride ions and feedback regulation by proline depend on whether NADPH or NADH acts as cosubstrate. New Phytol. 2014; 202: 911919.
Gimeno V , Syvertsen JP , Nieves M , Simn I , Martnez V , Garca-Snchez F. Additional nitrogen fertilization affects salt tolerance of lemon trees on different rootstocks. Sci. Hortic. 2009; 121: 298305.
Girousse C , Bournoville R , Bonnemain J.L. Water deficit-induced changes in concentrations in proline and some other amino acids in the phloem sap of alfalfa. Plant Physiol. 1996; 111: 109113.

Habash DZ , Bernard S , Schondelmaier J , Weyen J , Quarrie S.A. The genetics of nitrogen use in hexaploid wheat: N utilisation, development and yield. Theor. Appl. Genet. 2007; 114: 403419.
Habash DZ , Massiah AJ , Rong HL , Wallsgrove RM , Leigh R.A. The role of cytosolic glutamine synthetase in wheat. Ann. Appl. Biol. 2001; 138: 8389.
Hamidou F , Zombre G , Braconnier S. Physiological and biochemical responses of cowpea genotypes to water stress under glasshouse and field conditions. J. Agron. Crops 2007; 193: 229237.
Han KH , Hwang C.H. Salt tolerance enhanced by transformation of a P5CS gene in carrot. J. Plant Biotechnol. 2003; 5: 149153.
Hanson AD , Nelsen CE , Pedersen AR , Everson E.H. Capacity for proline accumulation during water stress in barley and its implications for breeding for drought resistance. Crop Sci. 1979; 19: 489493.
Hare PD , Cress W.A. Metabolic implications of stress-induced proline accumulation in plants. Plant Growth Regul. 1997; 21: 79102.
Hare PD , Cress WA, , Van Staden J. Dissecting the roles of osmolyte accumulation during stress. Plant Cell Environ. 1998; 21: 535553.
Hare PD , Cress WA, , Van Staden J. Proline synthesis and degradation: A model system for elucidating stress-related signal transduction. J. Exp. Bot. 1999; 50: 413434.
Hayano-Kanashiro C , Calderon-Vazquez C , Ibarra-Laclette E , Herrera-Estrella L , Simpson J. Analysis of gene expression and physiological responses in three Mexican maize landraces under drought stress and recovery irrigation. PLoS ONE 2009; 4: e7531.
Hayashi F , Ichino T , Osanai R , Wada K. Oscillation and regulation of proline content by P5CS and ProDH gene expressions in the light/dark cycles in Arabidopsis thaliana L. Plant Cell Physiol. 2000; 41: 10961101.
He J , Zhao X , Laroche A , Lu ZX , Liu H , Li Z. Genotyping-by-sequencing (GBS), an ultimate marker-assisted selection (MAS) tool to accelerate plant breeding. Front. Plant Sci. 2014; 5: 484.
Hirel B , Bertin P , Quillere I , Bourdoncle W , Attagnant C , Dellay C , Gouy A , Cadiou S , Retailliau C , Falque M , Gallais A. Towards a better understanding of the genetic and physiological basis for nitrogen use efficiency in maize. Plant Physiol. 2001; 125: 12581270.
Hirel B , Phillipson B , Murchie E , Suzuki A , Kunz C , Ferrario S , Limami A , Chaillou S , Deleens E , Brugire N , Chaumont-Bonnet M , Foyer C , Morot-Gaudry J-F. Manipulating the pathway of ammonium assimilation in transgenic non-legumes and legumes. J. Plant Nutr. Soil Sci. 1997; 160: 283290.
Hmida-Sayari A , Gargouri-Bouzid R , Bidani A , Jaoua L , Savour A , Jaoua S. Overexpression of 1-pyrroline-5-carboxylate synthetase increases proline production and confers salt tolerance in transgenic potato plants. Plant Sci. 2005; 169: 746752.
Hong Z , Lakkineni K , Zhang Z , Verma D.P.S. Removal of feedback inhibition of 1-pyrroline-5-carboxylate synthetase results in increased proline accumulation and protection of plants from osmotic stress. Plant Physiol. 2000; 122: 11291136.
Hoque A , Okuma E , Banu NA , Nakamura Y , Shimoishi Y , Murata Y. Exogenous proline mitigate the detrimental effect of salt stress more than exogenous betaine by increasing antioxidant enzyme activities. Plant Physiol. 2007; 164: 553561.
Hoshida H , Tanaka Y , Hibino T , Hayashi Y , Tanaka A , Takabe T , Takabe T. Enhanced tolerance to salt stress in transgenic rice that overexpresses chloroplast glutamine synthetase. Plant Mol. Biol. 2000; 43: 103111.
Hsu SY , Hsu YT , Kao C.H. The effect of polyethylene glycol on proline accumulation in rice leaves. Biol. Plant. 2003; 46: 7378.
Hu CAA , Delauney AJ , Verma D.P.S. A bifunctional enzyme 1-pyrroline-5- carboxylate synthetase catalyzes the first two steps in proline biosynthesis in plants. Proc. Natl. Acad. Sci. USA 1992; 89: 93549358.
Huang Z , Zhao L , Chen D , Liang M , Liu Z , Shao H , Long X. Salt stress encourages proline accumulation by regulating proline biosynthesis and degradation in Jerusalem artichoke plantlets. PLoS ONE 2013; 8: 4.
Igarashi Y , Yoshiba Y , Sanada Y , Yamaguchi-Shinozaki K. Characterization of the gene for 1-pyrroline-5-carboxylate synthetase and correlation between the expression of the gene and salt tolerance in Oryza sativa L. Plant Mol. Biol. 1997; 33: 857865.
Islam MM , Hoque MA , Okuma E , Banu MN , Shimoishi Y , Nakamura Y , Murata Y. Exogenous proline and glycinebetaine increase antioxidant enzyme activities and confer tolerance to cadmium stress in cultured tobacco cells. J. Plant Physiol. 2009; 166: 15871597.
Kandpal RP , Rao N.A. Alterations in the biosynthesis of proteins and nucleic acids in finger millet (Eleucine coracana) seedlings during water stress and the effect of proline on protein biosynthesis. Plant Sci. 1985; 40: 7379.
Kaneshiro ES , Holz GG Jr , Dunham P.B. Osmoregulation in a marine ciliate, Miamiensis avidus. II. Regulation of intracellular free amino acids. Biol. Bull. 1969; 137: 161169.
Kant S , Kant P , Lips H , Barak S. Partial substitution of NO3 by NH4+ fertilization increases ammonium assimilating enzyme activities and reduces the deleterious effects of salinity on the growth of barley. J. Plant Physiol. 2007; 164: 303311.
167 Kant S , Kant P , Raveh E , Barak S. Evidence that differential gene expression between the halophyte, Thellungiella halophila, and Arabidopsis thaliana is responsible for higher levels of the compatible osmolyte proline and tight control of Na + uptake in T. halophila. Plant Cell Environ. 2006; 29: 12201234.
Karl TR , Arguez A , Huang B , Lawrimore JH , McMahon JR , Menne MJ , Peterson TC , Vose RS , Zhang H.M. Possible artifacts of data biases in the recent global surface warming hiatus. Science 2015; 348: 14691472.
Kavi Kishor PB , Hong Z , Miao GH , Hu CAA , Verma D.P.S. Overexpression of 1-pyrroline-5-carboxylate synthetase increases proline production and confers osmo-tolerance in transgenic plants. Plant Physiol. 1995; 108: 13871394.
Kavi Kishor PB , Sangam S , Amrutha RN , Sri Laxmi P , Naidu KR , Rao Krss , Sreenath Rao , Reddy KJ , Theriappan P , Sreenivasulu N . Regulation of proline biosynthesis, degradation, uptake and transport in higher plants: Its implications in plant growth and abiotic stress tolerance. Curr. Sci. 2005; 88: 424438.
Kavi Kishor PB , Sreenivasulu N. Is proline accumulation per se correlated with stress tolerance or is proline homeostasis a more critical issue? Plant Cell Environ. 2014; 37: 300311.
Kesari R , Lasky JR , Villamor Jg , Marais DLD , Chen YJC , Liu TW , Juenger TE , Verslues P.E. Intron-mediated alternative splicing of Arabidopsis P5CS1 and its association with natural variation in proline and climate adaptation. Proc. Natl. Acad. Sci. USA 2012; 109: 91979202.
Khedr HA , Abbas MA , Wahid AAA , Quick PW , Abogadallah G.M. Proline induces the expression of salt-stress-responsive proteins and may improve the adaptation of Pancratium maritimum L. to salt-stress. J. Exp. Bot. 2003; 392: 25532562.
Kiyosue T , Yoshiba Y , Yamaguchi-Shinozaki K , Shinozaki K. A nuclear gene encoding mitochondrial proline dehydrogenase, an enzyme involved in proline metabolism, is upregulated by proline but downregulated by dehydration in Arabidopsis. Plant Cell 1996; 8: 13231335.
Knight H , Trewavas AJ , Knight M.R. Calcium signalling in Arabidopsis responding to drought and salinity. Plant J. 1997; 12: 10671078.
Kohl DH , Kennelly EJ , Zhu Y , Schubert KR , Shearer G. Proline accumulation, nitrogenase (C2 H2 reducing) activity and activities of enzymes related to proline metabolism in drought-stressed soybean nodules. J. Exp. Bot. 1991; 240: 831837.
Kohl DH , Schubert KR , Carter MB , Hagedorn CH , Shearer G. Proline metabolism in N2-fixing root nodules: Energy transfer and regulation of purine synthesis. Proc. Natl. Acad. Sci. USA 1988; 85: 20362040.
Kozano-Juste, Cutler SR. Plant genome engineering full bloom. Trends Plant Sci. 2014; 19: 284287.
Kumar V , Shr iram V , Kavi Kishor PB , Jawali N , Shitole M.G. Enhanced proline accumulation and salt stress tolerance of transgenic indica rice by over-expressing P5CSF129A gene. Plant Biotech. Rep. 2010; 4: 3748.
Le Rudulier D , Strom AR , Dandekar LT Smith , Valentine R.C. Molecular biology of osmoregulation. Science 1984; 224: 10641068.

Lea PJ , Azevedo R.A. Nitrogen use efficiency. 2. Amino acid metabolism. Ann. Appl. Biol. 2007; 151: 269275.
Lea PJ , Miflin B.J. Nitrogen assimilation and its relevance to crop improvement. Annu. Plant Rev. 2010; 42: 140.
Lehmann S , Funck D , Szabados L , Rentsch D. Proline metabolism and transport in plant development. Amino Acids 2010; 39: 949962.
Less H , Galili G. Principal transcriptional programs regulating plant amino acid metabolism in response to abiotic stresses. Plant Physiol. 2008; 147: 316330.
Liu J , Zhu J.K. Proline accumulation and salt-stress-induced gene expression in a salt-hypersensitive mutant of Arabidopsis. Plant Physiol. 1997; 114: 591596.
Loggini B , Scartazza A , Brugnoli E , Navari-Izzo F. Antioxidative defense system, pigment composition, and photosynthetic efficiency in two wheat cultivars subjected to drought. Plant Physiol. 1999; 119: 10911100.
Low P.S. Molecular basis of the biological compatibility of natures osmolytes. In: Gilles R , Gilles-Baillien M. (eds.). Transport Processes, Iono- and Osmoregulation, 469477. Berlin: Springer-Verlag, 1985.
Mafakheri A , Siosemardeh A , Bahramnejad B , Struik, PC , Sohrabi Y. Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. Aust. J. Crop Sci. 2010; 4: 580585.
Maggio A , Miyazaki S , Veronese P , Fuijita T , Ibeas JI , Damsz B , Narasmhan ML , Hasegawa PM , Joly RJ , Bressan R.A. Does proline accumulation play an active role in stress-induced growth reduction? Plant J. 2002; 31: 699712.
Mkel P , Peltonen-Sainio P , Jokinen K , Pehu E , Setl H , Hinkkanen R , Somersalo S: Uptake and translocation of foliar-applied glycinebetaine in crop plants. Plant Sci. 1996: 121: 221230.
Mani S , Van De Cotte B , Van Montagu M , Verbruggen N. Altered levels of proline dehydrogenase cause hypersensitivity to proline and its analogs in Arabidopsis. Plant Physiol. 2002; 128: 7383
Martin A , Lee J , Kichey T , Gerentes D , Zivy M , Tatout C , Dubois F , Balliau T , Valot B , Davanture M , Terc-Laforgue T. Two cytosolic glutamine synthetase isoforms of maize are specifically involved in the control of grain production. Plant Cell 2006; 18: 32523274.
Martinelli T , Whittaker A , Bochicchio A , Vazzana C , Akira Suzuki, Masclaux-Daubresse C. Amino acid pattern and glutamate metabolism during dehydration stress in the resurrection plant Sporobolus stapfianus: A comparison between desiccation-sensitive and desiccation-tolerant leaves. J. Exp. Bot. 2007; 58: 30373046.
Masclaux C , Quillere I , Gallais A , Hirel B. The challenge of remobilization in plant nitrogen economy. A survey of physio-agronomic and molecular approaches. Ann. Appl. Biol. 2001; 138: 6981.
Masoumi H , Darvish F , Daneshian J , Nourmohammadi G , Habibi D. Chemical and biochemical responses of soybean (Glycine max L.) cultivars to water deficit stress. Aust. J. Crop Sci. 2011; 5: 544553.
Mattioli R , Biancucci M , Lonoce C , Costantino P , Trovato M. Proline is required for male gametophyte development in Arabidopsis. BMC Plant Biol. 2012; 12: 236.
Mattioli R , Costantino P , Trovato M: Proline accumulation in plants:not only stress. Plant signal Behav. 2009a; 4: 10161018.
Mattioli R , Falasca G , Sabatini S , Costantino P , Altamura MM , Trovato M. The proline biosynthetic genes P5CS1 and P5CS2 play overlapping roles in Arabidopsis flower transition but not in embryo development. Physiol. Plant. 2009b; 137: 7285.
Mattioli R , Marchese D , DAngeli S , Altamura MM , Costantino P , Trovato M. Modulation of intracellular proline levels affects flowering time and inflorescence architecture in Arabidopsis. Plant Mol. Biol. 2008; 66: 277288.
168 Mauro ML , Trovato M , De Paolis A , Gallelli A , Costantino P , Altamura M.M. The plant oncogene rolD stimulates flowering in transgenic tobacco plants. Dev. Biol. 1996; 180: 693700.
Micheu S , Crailsheim K , Leonhard B. Importance of proline and other amino acids during honeybee flight (Apis mellifera carnica POLLMANN). Amino Acids 2000; 18: 157175.
Miflin BJ , Lea P.J. Ammonia assimilation. In: Miflin BJ (ed.). Biochemistry of Plants, 169202. New York: Academic Press, 1980.
Miller G , Honig A , Stein H , Suzuki N , Mittler R , Zilberstein A. Unraveling 1-pyrroline-5-carboxylate-proline cycle in plants by uncoupled expression of proline oxidation enzymes. J. Biol. Chem. 2009; 284: 2648226492.
Molinari HBC , Marur CJ , Daros E , Campos MKF , De Carvalho Jfrp , Filho JCB , Pereira LFP , Vieira L.G.E. Evaluation of the stress-inducible production of proline in transgenic sugarcane (Saccharum spp.): Osmotic adjustment, chlorophyll fluorescence and oxidative stress. Physiol. Plant. 2007; 130: 218229.
Moussa HR , Abdel-Aziz S.M. Comparative response of drought tolerant and drought sensitive maize genotypes to water stress. Aust. J. Crop Sci. 2008; 1: 331336.
Mwenye OJ , van Rensburg L , van Biljon A , van der Merwe R. The role of proline and root traits on selection for drought-stress tolerance in soybeans: A review. S. Afr. J. Plant Soil 2016; 34: 112.
Nakabayashi R , Saito K. Integrated metabolomics for abiotic stress responses in plants. Curr. Opin. Plant Biol. 2015; 24: 1016.
Nakabayashi R , Yonekura-Sakakibara K , Urano K , Suzuki M , Yamada Y , Nishizawa T , Matsuda F , Kojima M , Sakakibara H , Shinozaki K , Michael A.J. Enhancement of oxidative and drought tolerance in Arabidopsis by overaccumulation of antioxidant flavonoids. Plant J. 2014; 77: 367379.
Nanjo T , Kobayashi M , Yoshiba Y , Kakubari Y , Yamaguchi-Shinozaki K , Shinozaki K. Antisense suppression of proline degradation improves tolerance to freezing and salinity in Arabidopsis. FEBS Lett. 1999; 461: 205210.
Obara M , Kajiura M , Fukuta Y , Yano M , Hayashi M , Yamaya T , Sato T. Mapping of QTLs associated with cytosolic glutamine synthetase and NADH-glutamate synthase in rice (Oryza sativa L.). J. Exp. Bot. 2001; 52: 12091217.
Okumoto S , Funck D , Trovato M , Forlani G. Editorial: Amino acids of the glutamate family: Functions beyond primary metabolism. Front. Plant Sci. 2016; 7: 318.
Oliveira IC , Brears T , Knights TJ , Clark A , Coruzzi G.M. Overexpression of cytosolic glutamate synthetase. Relation to nitrogen, light, and photorespiration. Plant Physiol. 2002; 129: 11701180.
Orsel M , Moison M , Clouet V , Thomas J , Leprince F , Canoy AS , Just J , Chalhoub B , Masclaux-Daubresse C. Sixteen cytosolic glutamine synthetase genes identified in the Brassica napus L. genome are differentially regulated depending on nitrogen regimes and leaf senescence. J. Exp. Bot. 2014; 65: 39273947.
Parre E , Ghars MA , Leprince AS , Thiery L , Lefebvre D , Bordenave M , Richard L , Mazars C , Abdelly C , Savour A. Calcium signaling via phospholipase C is essential for proline accumulation upon ionic but not nonionic hyperosmotic stresses in Arabidopsis. Plant Physiol. 2007; 144: 503512.
Peng Z , Lu Q , Verma D.P. Reciprocal regulation of 1-pyrroline-5-carboxylate synthetase and proline dehydrogenase genes controls proline levels during and after osmotic stress in plants. Mol. Gen. Genet. 1996; 253: 334341.
Petrusa LM , Winicov I. Proline status in salt tolerant and salt sensitive alfalfa cell lines and plants in response to NaCl. Plant Physiol. Biochem. 1997; 35: 303310.
Phang J.M. The regulatory functions of proline and pyrroline-5-carboxylic acid. Curr. Top Cell Regul. 1985; 25: 91132.
Poulin R , Larochelle J , Hellebust J.A. The regulation of amino acid metabolism during hyperosmotic stress in Acanthamoetla castellanii. J. Exp. Zool. 1987; 243: 365378.
Rajendrakumar SC , Reddy BV , Reddy A.R. Prolineprotein interactions: Protection of structural and functional integrity of M4 lactate dehydrogenase. Biochem. Biophys. Res. Commun. 1994; 201: 957963.

Rashid A , Waraich EA , Ashraf MY , Shamim A , Aziz T. Does nitrogen fertilization enhance drought tolerance in sunflower? A review. J. Plant Nutr. 2014; 37: 942963.
Rentsch D , Schmidt S , Tegeder M. Transporters for uptake and allocation of organic nitrogen compounds in plants. FEBS Lett. 2007; 581: 22812289.
Rhodes D , Handa S , Bressan R.A. Metabolic changes associated with adaptation of plant cells to water stress. Plant Physiol. 1986; 82: 890903.
Rustgi S , Joshi A , Moss H , Riesz P. ESR of spin trapped radicals of aqueous solutions of amino acids: Reactions of the hydroxyl radical. Int. J. Rad. Biol. Rel. Stud. Phys. Chem. Med. 1977; 31: 415440.
Sagi M , Dovrat A , Kipnis T , Lips S.H. Nitrate reductase, phosphoenolpyruvate carboxylase and glutamine synthetase in annual ryegrass as affected by salinity and nitrogen. J. Plant Nutr. 1998; 21: 707723.
Sairam RK , Rao KV , Srivastava G.C. Differential response of wheat genotypes to long term salinity stress in relation to oxidative stress, antioxidant activity and osmolyte concentration. Plant Sci. 2002; 163: 10371046.
Samach A , Onouchi H , Gold SE , Dittha GS , Schwarz-Sommer S , Yanofsky MF , Coupland G. Distinct roles of CONSTANS target genes in reproductive development of Arabidopsis. Science 2000; 288: 16131616.
Saranga Y , Rhodes D , Janick J. Changes in amino acid composition associated with tolerance to partial desiccation of celery somatic embryos. J. Am. Soc. Hort. Sci. 1992; 117: 337341.
Savour A , Hua XJ , Bertauche N , Van Montagu M , Verbruggen N. Abscisic acid-independent and abscisic acid-dependent regulation of proline biosynthesis following cold and osmotic stresses in Arabidopsis thaliana. Mol. Gen. Genet. 1997; 254: 104109.
Savour A , Jaoua S , Hua XJ , Ardiles W , VanMontagu M , Verbruggen N. Isolation and characterization, and chromosomal location of a gene encoding the 1-pyrroline- 5-carboxylate synthetase in Arabidopsis. FEBS Lett. 1995; 372: 1319.
Sawahel W , Hassan A.H. Generation of transgenic wheat plants producing high levels of the osmoprotectant proline. Biotechnol. Lett. 2002; 24: 721.
Sayed MA , Schumann H , Pillen K , Naz AA , Lon J. AB-QTL analysis reveals new alleles associated to proline accumulation and leaf wilting under drought stress conditions in barley (Hordeum vulgare L.). BMC Genet. 2012; 13: 61.
Schwacke R , Grallath S , Breitkreuz KE , Stransky H , Frommer WB , Rentsch D. LeProT1, a transporter for proline, glycine betaine, and -amino butyric acid in tomato pollen. Plant Cell 1999; 11: 377391.
169 Seabra AR , Carvalho H.G. Glutamine synthetase in Medicago truncatula, unveiling new secrets of a very old enzyme. Front. Plant Sci. 2015; 6: 578.
Sharma S , Shinde S , Verslues P.E. Functional characterization of an ornithine cyclodeaminase-like protein of Arabidopsis thaliana. BMC Plant Biol. 2013; 13: 182.
Sharma S , Verslues P.E. Mechanisms independent of abscisic acid (ABA) or proline feedback have a predominant role in transcriptional regulation of proline metabolism during low water potential and stress recovery. Plant Cell Environ. 2010; 33: 18381851.
Sharma S , Villamor JG , Verslues P.E. Essential role of tissue-specific proline synthesis and catabolism in growth and redox balance at low water potential. Plant Physiol. 2011; 157: 292304.
Signorelli S , Arellano J.B. , Melo, T.B. ; Borsani, O ; Monza, J. Proline Does Not Quench Singlet Oxygen: Evidence to Reconsider Its Protective Role in Plants. Plant Physiol. Biochem. 2013; 64, 80-83.
Signorelli S , Coitio EL , Borsani O , Monza J. Molecular mechanisms for the reaction between .OH radical and proline: Insights on the role as reactive oxygen species scavenger in plant stress. J. Phys. Chem. 2014; 118: 3747.
Singh TN , Aspinall D , Paleg L.G. Proline accumulation and varietal adaptability to drought in barley: A potential metabolic measure of drought resistance. Nat. New Biol. 1972; 236: 188190.
Slafer GA , Araus JL , Royo C , Del Moral LFG . Promising eco-physiological traits for genetic improvement of cereal yields in Mediterranean environments. Ann. Appl. Biol. 2005; 146: 6170.
Smirnoff N. The role of active oxygen in the response of plants to water deficit and desiccation. New Phytol. 1993; 125: 2758.
Smirnoff N , Cumbes Q.J. Hydroxyl radical scavenging activity of compatible solutes. Phytochemistry 1989; 28: 10571060.
Stewart CR , Voetberg G , Rapayati P.J. The effects of benzyladenine, and cordycepin on wilting-induced abscisic acid and proline accumulation and abscisic acid- and salt induced proline accumulation in barley leaves. Plant Physiol. 1986; 82: 703707.
Strizhov N , brahm E , kresz L , Blickling S , Zilberstein A , Schell J , Koncz C , Szabados L. Differential expression of two P5CS genes controlling proline accumulation during salt-stress requires ABA and is regulated by ABA1, ABI1 and AXR2 in Arabidopsis. Plant J. 1997; 12: 557569.
Su J , Wu R. Stress-inducible synthesis of proline in transgenic rice confers faster growth under stress conditions than that with constitutive synthesis. Plant Sci. 2004; 166: 941948.
Surekha CH , Nirmala Kumari K , Aruna LV , Suneetha G , Arundhati A , Kavi Kishor P.B. Expression of the Vigna aconitifolia P5CSF129A gene in transgenic pigeon pea enhances proline accumulation and salt tolerance. Plant Cell Tissue Organ Cult. 2013; 116: 2736.
Szabados L , Savour A. Proline: A multifunctional amino acid. Trends Plant Sci. 2010; 15: 8997.
Szkely G , brahm E , Csplo , Rigo G , Zsigmond L , Csiszr J , Ayaydin F , Strizhov N , Jsik J , Schmelzer E , Koncz C , Szabados L : Duplicated P5CS genes of Arabidopsis play distinct roles in stress regulation and developmental control of proline biosynthesis. Plant J. 2008; 53: 1128.
Tabuchi M , Sugiyama K , Ishiyama K , Inoue E , Sato, T , Takahashi H , Yamaya T. Severe reduction in growth rate and grain filling of rice mutants lacking OsGS1;1, a cytosolic glutamine synthetase1;1. Plant J. 2005; 42: 641651.
Taira M , Valtersson U , Burkhardt B , Ludwig R.A. Arabidopsis thaliana GLN2-encoded glutamine synthetase is dual targeted to leaf mitochondria and chloroplasts. Plant Cell 2004; 16: 20482058.
Takagi H , Sakai K , Morida K , Nakamori S. Proline accumulation by mutation or disruption of the proline oxidase gene improves resistance to freezing and desiccation stresses in Saccharomyces cerevisiae. FEMS Microbiol. Lett. 2000; 184: 103108.
Tanksley SD , McCouch S.R. Seed banks and molecular maps: Unlocking genetic potential from the wild. Science 1997; 227: 10361066.
Teixeira J , Fidalgo F. Salt stress affects glutamine synthetase activity and mRNA accumulation on potato plants in an organ-dependent manner. Plant Physiol. Biochem. 2009; 47: 807813.
Temple SJ , Vance CP , Gantt S.J. Glutamate synthase and nitrogen assimilation. Trends Plant Sci. 1998; 3: 5156.
Thiery L , Leprince AS , Lefebvre D , Ghars MA , Debarbieux E , Savour A. Phospholipase D is a negative regulator of proline biosynthesis in Arabidopsis thaliana. J. Biol. Chem. 2004; 279: 1481214818.
Thomsen HC , Eriksson D , Mller IS , Schjoerring J.K. Cytosolic glutamine synthetase: A target for improvement of crop nitrogen use efficiency? Trends Plant Sci. 2014; 19: 656663.
Torres-Franklin ML , Contour-Ansel D , Zuily-Fodil Y , Pham-Thi A.T. Molecular cloning of glutathione reductase cDNAs and analysis of GR gene expression in cowpea and common bean leaves during recovery from moderate drought stress. J. Plant Physiol. 2008; 165: 514521.
Trovato M , Maras B , Linhares F , Costantino P. The plant oncogene rolD encodes a functional ornithine cyclodeaminase. Proc. Natl. Acad. Sci. USA 2001; 98: 1344913454.

Trovato M , Mattioli R , Costantino P. Multiple roles of proline in plant stress tolerance and development. Rend. Lincei 2008; 19: 325346.

Trovato M , Mauro ML , Costantino P , Altamura M.M. Agrobacterium rhizogenes rolD gene is developmentally regulated in transgenic tobacco. Protoplasma 1997; 197: 111120.

van Heerden PDR , de Villiers O.T. Evaluation of proline accumulation as an indicator of drought tolerance in spring wheat cultivars. S. Afr. J. Plant Soil 1996; 13: 1721.

van Rensburg L , Kruger GHJ , Kruger H. Proline accumulation as drought tolerant criterion: Its relationship to membrane integrity and chloroplast ultrastructure in Nicotiana tabacum L. J. Plant Physiol. 1993; 141: 188194.

Veeranagamallaiah G , Chandraobulreddy P , Jyothsnakumari G , Sudhakar C. Glutamine synthetase expression and pyrroline-5-carboxylate reductase activity influence proline accumulation in two cultivars of foxtail millet (Setaria italica L.) with differential salt sensitivity. Environ. Exp. Bot. 2007; 60: 239244.

Vlez-Bermdez, I. C. , Schmidt, W. The conundrum of discordant protein and mRNA expression. Are plants special? Front. Plant Sci. 2014; 5: 619.

Vendruscolo ECG , Schuster I , Pileggi M , Scapim CA , Molinari HBC , Marur CJ , Vieira L.G. Stress-induced synthesis of proline confers tolerance to water deficit in transgenic wheat. J. Plant Physiol. 2007; 164: 13671376.

Verbruggen N , Hermans C. Proline accumulation in plants: A review. Amino Acids 2008; 35: 753759.

170 Verbruggen N , Villarroel R , Van Montagu M. Osmoregulation of a pyrroline-5-carboxylate reductase gene in Arabidopsis. Plant Physiol. 1993; 103: 771781.

Verslues PE , Sharma S. Proline metabolism and its implications for plant-environment interaction. Arabidopsis Book 2010; 8: e0140.

Verslues PE , Sharp R.E. Proline accumulation in maize (Zea mays L.) primary roots at low water potentials. II. Metabolic source of increased proline deposition in the elongation zone. Plant Physiol. 1999; 119: 13491360.

Wehner G , Balko C , Humbeck K , Zyprian E , Ordon F. Expression profiling of genes involved in drought stress and leaf senescence in juvenile barley. BMC Plant Biol. 2016; 16: 3.

Whan A , Robinson N , Lakshmanan P , Schmidt S , Aitken K. A quantitative genetics approach to nitrogen use efficiency in sugarcane. Funct. Plant Biol. 2010; 37: 448454.

Widodo , Patterson JH , Newbigin Ed , Tester M , Bacic A , Roessner U. Metabolic responses to salt stress of barley (Hordeum vulgare L.) cultivars, Sahara and Clipper, which differ in salinity tolerance. J. Exp. Bot. 2009; 60: 40894103.

Winkel-Shirley B. Biosynthesis of flavonoids and effect of stress. Curr. Opin. Plant Biol. 2002; 5: 218223.

Winter G , Todd CD , Trovato M , Forlani G , Funck D. Physiological implications of arginine metabolism in plants. Front. Plant Sci. 2015; 6: 534.

Xin Z , Browse J. eskimo1 mutants of Arabidopsis are constitutively freezing-tolerant. Proc. Natl. Acad. Sci. USA 1998; 95: 77997804.

Xu J , Yin H , Li X. Protective effects of proline against cadmium toxicity in micropropagated hyperaccumulator, Solanum nigrum L. Plant Cell Rep. 2009; 28: 325333.

Yamchi A , Jazii FR , Mousavi A , Karkhane A.A. Proline accumulation in transgenic tobacco as a result of expression of Arabidopsis 1-Pyrroline-5-carboxylate synthetase (P5CS) during osmotic stress. J. Plant Biochem. Biotech. 2007; 16: 915.

Yang H , Tao Y , Zheng Z , Li C , Sweetingham MW , Howieson J.G. Application of next-generation sequencing for rapid marker development in molecular plant breeding: A case study on anthracnose disease resistance in Lupinus angustifolius L. BMC Genom. 2012; 13: 1.

Yian Z , Guo S , Shu S , Sun J , Tezuka T. Effects of proline on photosynthesis, root reactive oxygen species (ROS) metabolism in two melon cultivars (Cucumis melo L.) under NaCl stress. Afr. J. Biotech. 2011; 10: 1838118390.

Yoshiba Y , Kiyosue T , Katagiri T , Ueda H , Wada K , Harada Y , Shinozaki K. Correlation between the induction of a gene for 1-pyrroline-5-carboxylate synthetase and the accumulation of proline in Arabidopsis under osmotic stress. Plant J. 1995; 7: 751760.

Yoshiba Y , Kiyosue T , Nakashima K , Yamaguchi-Shinozaki K , Shinozaki K . Regulation of levels of proline as an osmolyte in plants under water stress. Plant Cell Physiol. 1997; 38: 10951102.

Yoshiba Y , Nanjo T , Miura S , Yamaguchi-Shinozaki K , Shinozaki K. Stress-responsive and developmental regulation of 1-pyrroline-5-carboxylate synthetase 1 (P5CS1) gene expression in Arabidopsis thaliana. BBRC 1999; 261: 766772.

Zhang CS , Lu Q , Verma D.P.S. Removal of feedback inhibition of 1-pyrroline-5-carboxylate synthetase, a bifunctional enzyme catalyzing the first two steps of proline biosynthesis in plants. J. Biol. Chem. 1995; 270: 2049120496.

Zhao MG , Chen L , Zhang LL , Zhang W.H. Nitric reductase-dependent nitric oxide production is involved in cold acclimation and freezing tolerance in Arabidopsis. Plant Physiol. 2009; 151: 755767.

Zhu B , Su J , Chang M , Verma DPS , Fan YL , Wu R. Overexpression of a 1-pyrroline-5-carboxylate synthetase gene and analysis of tolerance to water- and salt-stress in transgenic rice. Plant Sci. 1998; 139: 4148.

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Abebe T , Guenzi AC , Martin B , Cushman J.C. Tolerance of mannitol-accumulating transgenic wheat to water stress and salinity. Plant Physiol. 2003; 131: 17481755.

Aeschbacher RA , Mller J , Boller T , Wiemkem A. Purification of the trehalase GMTRE1 from soybean nodules and cloning of its cDNA. GMTRE is expressed at low levels in multiple tissues. Plant Physiol. 1999; 119: 489495.

Agboma PC , Jones MGK , Peltonen Sainio P , Rita H , Pehu E. Exogenous glycine betaine enhances grain yield of maize, sorghum and wheat grown under two supplementary watering regimes. J. Agron. Crop. Sci. 1997a; 178(1): 2937.

Agboma PC , Sinclair TR , Jokinen K , Peltonen-Sainio P , Pehu E. An evaluation of the effect of exogenous glycinebetaine on the growth and yield of soybean: Timing of application, watering regimes and cultivars. Field Crops Res. 1997b; 54(1): 5164.

Aghdasi M , Schluepmann H , Smeekens S. Characterization of Arabidopsis seedlings growth and development under trehalose feeding. J. Cell Mol. Res. 2010; 2: 19.

Aghdasi M , Smeekens S , Schluepman H. Microarray analysis of gene expression patterns in Arabidopsis seedlings under trehalose, sucrose and sorbitol treatment. Int. J. Plant Prod. 2008; 2: 309320.

Ahmad R , Kim MD , Back KH , Kim HS , Lee, HS , Kwon SY , Murata N , Chung WI , Kwak S.S. Stress-induced expression of choline oxidase in potato plant chloroplasts confers enhanced tolerance to oxidative, salt and drought stresses. Plant Cell Rep. 2008; 27: 687698.

Ahmadi A , Emam Y , Pessarakli M. Biochemical changes in maize seedlings exposed to drought stress conditions at different nitrogen levels. Plant Nut. 2010; 33(4): 541556.

Akashi K , Miyake C , Yokota A. Citrulline, a novel compatible solute in drought tolerant wild watermelon leaves, is an efficient hydroxyl radical scavenger. FEBS Lett. 2001; 508: 438442.

Aldesuquy H.S. Glycine betaine and salicylic acid induced modification in water relations and productivity of drought wheat plants. J. Stress Physiol. Biochem. 2014, 10: 5573.

Ali Q. Exogenous use of some potential organic osmolytes in enhancing drought tolerance in maize (Zae mays L.). A thesis submitted in partial fulfillment of the requirements for the degree of doctor of philosophy. Botany Department, Faculty of Science, University of Agriculture, Faisalabad, Pakistan, 2011; p. 312.

Ali Q , Ashraf M. Exogenously applied glycine betaine enhances seed and seed oil quality of maize (Zea mays L.) under water deficit conditions. Environ. Exp. Bot. 2011; 71: 249259.

Ali Q , Ashraf M , Anwar F. Seed composition and seed oil antioxidant activity of maize under water stress. J. Am. Oil Chem. Soc. 2010; 87: 11791187.

Ali QF , Anwar M , Ashraf Saari N , Perveen R. Ameliorating effects of exogenously applied proline on seed composition, seed oil quality and oil antioxidant activity of maize (Zea mays L.) under drought stress. Int. J. Mol. Sci. 2013, 14: 818835.

183 Alia HH , Chen THH , Murata N. Transformation with a gene for choline oxidase enhances the cold tolerance of Arabidopsis during germination and early growth. Plant Cell Environ. 1998a; 21: 232239.

Alia HH , Sakamoto A , Murata N. Enhancement of the tolerance of Arabidopsis to high temperatures by genetic engineering of the synthesis of glycine betaine. Plant J. 1998b; 16: 155161.

Allakhverdiev SI , Hayashi H , Nishiyama Y , Ivanov AG , Aliev JA , Klimov VV , Murata N , Carpentier R. Glycinebetaine protects the D1/D2/Cytb559 complex of photosystem II against photo-induced and heat-induced inactivation. J. Plant Physiol. 2003; 160: 4149.

Almeida AM , Cardoso LA , Santos DM , Torn JM , Fevereiro P.S. Trehalose and its applications in plant biotechnology. In Vitro Cell Dev. Biol. Plant 2007b; 43: 167177.

Almeida AM , Santos M , Villalobos E , Arajo SS , van Dijck P , Leyman B , Cardoso LA , Santos D , Fevereiro PS , Torn J.M. Immunogold localization study of trehalose-6-phosphate synthase in leaf segments of wild type and transgenic tobacco plants expressing the AtTPS1 gene from Arabidopsis thaliana. Protoplasma 2007a; 230(1): 4149.

Al-Taweel K , Iwaki T , Yabuta Y , Shigeoka S , Murata N , Wadano A. A bacterial transgene for catalase protects translation of D1 protein during exposure of salt stressed tobacco leaves to strong light. Plant Physiol. 2007; 145: 258265.

Anjum SA , Saleem MF , Wang L , Bilal MF , Saeed A. Protective role of glycine betaine in maize against drought-induced lipid peroxidation by enhancing capacity of antioxidative system. Aust. J. Crop Sci. 2012; 6: 576583.

Ashraf M. Breeding for salinity tolerance in plants. Crit. Rev. Plant Sci. 1994; 13: 1742.

Ashraf M , Athar HR , Harris PJC , Kwon T.R. Some prospective strategies for improving crop salt tolerance. Adv. Agron. 2008; 97: 45110.

Ashraf M , Foolad M.R. Pre-sowing seed treatment-a shot gun approach to improve germination, plant growth, and crop yield under saline and non-saline conditions. Adv. Agron. 2005; 88: 223271.

Ashraf M , Foolad M.R. Roles of glycinebetaine and proline in improving plant abiotic stress resistance. Environ. Exp. Bot. 2007; 59: 206216.

Atkinson NJ , Urwin P.E. The interaction of plant biotic and abiotic stresses: From genes to the field. J. Exp. Bot. 2012; 63(10) : 35233543.

Avonce N , Leyman B , Mascorro-Gallardo JO , Van Dijck P , Thevelein JM , Iturriaga G. The Arabidopsis trehalose-6-P synthase AtTPS1 gene is a regulator of glucose, abscisic acid, and stress signaling. Plant Physiol. 2004; 136: 36493659.

Azevedo NAD , Prisco JT , Eneas FJ , Abreu CEB , Gomes F.E. Effect of salt stress on antioxidative enzymes and lipid peroxidation in leaves and roots of salt-tolerant and salt-sensitive maize genotypes. Environ. Exp. Bot. 2006; 56: 8794.

Bae H , Herman E , Bailey B , Bae HJ , Sicher R. Exogenous trehalose alters Arabidopsis transcripts involved in cell wall modification, abiotic stress, nitrogen metabolism, and plant defense. Physiol Plant. 2005; 125: 114126.

Baena-Gonzalez E , Rolland F , Thevelein JM , Sheen J. A central integrator of transcription networks in plant stress and energy signaling. Nature. 2007; 449: 938942.

Banu MN , Hoque MA , Watanabe-Sugimoto M , Islam MM , Uraji M , Matsuoka K , Nakamura Y , Murata Y. Proline and glycinebetaine ameliorated NaCl stress via scavenging of hydrogen peroxide and methylglyoxal but not superoxide or nitric oxide in tobacco cultured cells. Biosci. Biotechnol. Biochem., Research Support, Non-U.S. Govt. 2010; 74(10): 20432049.

Bartels D , Souer E. Molecular responses of higher plants to dehydration. In: Plant Responses to Abiotic Stress. Topics in Current Genetics. Berlin: Springer, 2003; 4: 938.

Bartels D , Sunkar R. Drought and salt tolerance in plants. Crit. Rev. Plant Sci. 2005; 24: 2358.

Ben Hassine A , Ghanem ME , Bouzid S , Lutts S. An inland and a coastal population of the Mediterranean xero-halophyte species Atriplex halimus L. differ in their ability to accumulate proline and glycine betaine in response to salinity and water stress. J. Environ. Bot. 2008; 59: 13151326.

Blum A. Drought resistance, water-use efficiency, and yield potential are they compatible, dissonant, or mutually exclusive? Aust. J. Agric. Res. 2005; 56: 11591168.

Bohnert HJ , Nelson DE , Jensen R.G. Adaptations to environmental stresses. Plant Cell. 1995; 7: 10991111.

Bolen DW , Baskakov I.V. The osmophobic effect: Natural selection of a thermodynamic force in protein folding. J. Mol. Biol. 2001; 310: 955963.

Brunk DG , Rich PJ , Rhodes D. Genotypic variation for glycine betaine among public in breds of maize. Plant Physiol. 1989; 91(3): 11221125.

Cechin I , Rossi SC , Oliveira VC , Fumis T.F. Photosynthetic responses and proline content of mature and young leaves of sunflower plants under water deficit. Photosynthetica 2006; 44: 143146.

Cha-Um S , Kirdmanee C. Effect of glycine betaine on proline, water use, and photosynthetic efficiencies, and growth of rice seedlings under salt stress. Turk. J. Agric. For. 2010; 34: 517527.

Cha-Um S , Supaibulwatana K , Kirdmanee C. Glycine betaine accumulation, physiological characterizations and growth efficiency in salt-tolerant and salt-sensitive lines of indica rice (Oryza sativa L. ssp. indica) in response to salt stress. J. Agron. Crops Sci. 2007; 193: 157166.

Chen TH , Murata N. Enhancement of tolerance of abiotic stress by metabolic engineering of betaines and other compatible solutes. Curr. Opin. Plant Biol. 2002; 5: 250257.

Chen TH , Murata N. Glycine betaine: An effective protectant against abiotic stress in plants. Trends Plant Sci. 2008; 13: 499505.

Chen TH , Murata N. Glycine betaine protects plants against a biotic stress: Mechanisms and biotechnological applications. Plant Cell Environ. 2011; 34: 120.

Chen WP , Li PH , Chen T.H. Glycine betaine increases chilling tolerance and reduces chilling-induced lipid peroxidation in Zea mays L. Plant Cell Environ. 2000; 23: 609618.

Cherian S , Reddy M , Ferreira R. Transgenic plants with improved dehydration-stress tolerance: Progress and future prospects. Biol. Plant. 2006; 50: 481495.

Chimenti CA , Marcantonio M , Hall A.J. Divergent selection for osmotic adjustment results in improved drought tolerance in maize (Zea maysL.) in both early growth and flowering phases. Field Crop Res. 2006; 95: 305315.

Ci H , Zhang N , Wang D. Enhancement of tobacco drought and salttolerance with introduced BADH gene. Acta Agron. Sin. 2007; 33: 13351339.

Colaco C , Sen S , Thangavelu M , Pinder S , Roser B. Extraordinary stability of enzymes dried in trehalose: Simplified molecular biology. Nature Biotech. 1992; 10: 10071011.

184 Cortina C , Culiez-Maci F.A. Tomato abiotic stress enhanced tolerance by trehalose biosynthesis. Plant Sci. 2005; 169: 7582.

Crowe JH , Crowe LM , Chapman D. Preservation of membranes in anhydrobiotic organisms: The role of trehalose. Science 1984; 223: 701703.

Cui XH , Hao FS , Chen H , Chen J , Wang X.C. Expression of the Vicia fabaVfPIP1 gene in Arabidopsis thaliana plants improves their drought resistance. J. Plant Res. 2008; 121(2): 207214.

Dawood MG , Sadak M Sh . Physiological role of glycinebetaine in alleviating the deleterious effects of drought stress on canola plants (Brassica napus L.). Middle East J. Agric. Res. 2014; 3(4): 943954.

Delauney AJ , Verma D.P.S. Proline biosynthesis and osmoregulation in plants. Plant J. 1993; 4: 215223.

Demiral T , Trkan I. Exogenous glycine betaine affects growth and proline accumulation and retards senescence in two rice cultivars under NaCl stress. Environ. Exp. Bot. 2006; 56: 7279.

Djilianov D , Georgieva T , Moyankova D , Atanassov A , Shinozaki K , Smeeken SCM , Verma D.P.S. , Murata N. Improved abiotic stress tolerance in plants by accumulation of osmoprotectants-gene transfer approach. Biotechnol. Biotechnol. Equip. 2005; 19(sup3): 6371.

Eastmond PJ , Graham I.A. Trehalose metabolism: A regulatory role for trehalose-6-phosphate? Curr Opin Plant Biol. 2003; 6: 231235.

Eastmond PJ , Li Y , Graham I.A. Is trehalose-6-phosphate a regulator of sugar metabolism in plants? J. Exp. Bot. 2003; 54: 533537.

Eastmond PJ , Van Dijken A , Spielman M , Kerr A , Tissier A , Dickinson, HG , Jones JD , Smeekens SC , Graham I.A. Trehalose-6-phosphate synthase 1, which catalyses the first step in trehalose synthesis, is essential for Arabidopsis embryo maturation. Plant J. 2002; 29: 225235.

Elbein A.D. The metabolism of a,a- Trehalose. Adv. Carbohydr. Chem. Biochem. 1974; 30: 227256.

Elbein AD , Pan YT , Pastuszak I. Carrol D. New insights on trehalose: A multifunctional molecule. Glycobiology 2003; 13: 17R27R.

Farooq M , Wahid A , Kobayashi N , Fujita D , Basra S.M.A. Plant drought stress: Effects, mechanisms and management. Agron. Sustain. Dev. 2009; 29: 185212.

Farooq M , Wahid A , Lee DJ , Cheema SA , Aziz T. Comparative time course action of the foliar applied glycinebetaine, salicylic acid, nitrous oxide, brassinosteroids and spermine in improving drought resistance of rice. J. Agron. Crop Sci. 2010; 196: 336345.

Fernandez O , Bthencourt L , Quero A , Sangwan RS , Clement C. Trehalose and plant stress responses: Friend or foe? Trends Plant Sci. 2010; 15: 409417.

Fillinger S , Chaveroche MK , van Dijck P , de Vries R , Ruijter G , Thevelein T , dEnfert C . Trehalose is required for the acquisition of tolerance to a variety of stresses in the filamentous fungus Aspergillus nidulans. Microbiology 2001; 147: 18511862.

Foster AJ , Jenkinson JM , Talbot N.J. Trehalose synthesis and metabolism are required at different stages of plant infection by Magnaporthe grisea. EMBO J. 2003; 22: 225235.

Fougere F , Le Rudulier D , Streeter J.G. Effects of salt stress on amino acid, organic acid, and carbohydrate composition of roots, bacteroids, and cytosol of alfalfa (Medicago sativa L.). Plant Physiol. 1991; 96: 12281236.

Gaff D. Tobacco-plant desiccation tolerance. Nature (London) 1996; 382(6591): 502.

Gao M , Sakamoto A , Miura K , Murata N , Sugiura A , Tao R. Transformation of Japanese persimmon (Diospyroskaki Thunb.) with a bacterial gene for choline oxidase. Mol. Breed. 2000; 6: 501510.

Garcia AB , Engler J , Iyer S , Gerats T , Van Montagu M , Caplan A.B. Effects of osmoprotectants upon NaCl stress in rice. Plant Physiol. 1997; 115(1): 159169.

Garg AK , Kim JK , Owens TG , Ranwala AP , Choi YD , Kochian LV , Wu R.J. Trehalose accumulation in rice plants confers high tolerance levels to different abiotic stresses. Proc. Nat. Acad. Sci. USA 2002; 99: 1589815903.

Ghasempour HR , Gaff DF , Williams R , Gianello R.D. Contents of sugars in leaves of drying desiccation tolerant flowering plants, particularly grasses. Plant Growth Regul. 1998; 24: 185191.

Gibon Y , Bessieres MA , Larher F. Is glycine betaine a non-acompatible solute in higher plants that do not accumulate it? Plant Cell Environ. 1997; 20: 329340.

Giri J. Glycinebetaine and abiotic stress tolerance in plants. Plant Signal. Behav. 2011; 6(11): 17461751.

Girija C , Smith BN , Swamy P.M. Interactive effects of sodium chloride and calcium chloride on the accumulation of proline and glycine betaine in peanut (Arachis hypogaea L.). Environ. Exp. Bot. 2002; 47: 110.

Goddijn OJM , Van Dun K. Trehalose metabolism in plants. Trends Plant Sci. 1999; 4(8): 315319.

Goddijn OJ , Verwoerd TC , Voogd E , Krutwagen RW , de Graaf PT , van Dun K , Poels J , Ponstein AS , Damm B , Pen J. Inhibition of trehalase activity enhances trehalose accumulation in transgenic plants. Plant Physiol. 1997; 113: 181190.

Goel D , Singh AK , Yadav V , Babbar SB , Murata N , Bansal K.C. Transformation of tomato with a bacterial codA gene enhances tolerance to salt and water stresses. J. Plant Physiol. 2011; 168: 12861294.

Grennan A.K. The role of trehalose biosynthesis in plants. Plant Physiol. 2007; 144: 35.

Griffiths H , Parry M.A.J. Plant responses to water stress. Ann. Bot. 2002; 89: 801802.

Groppa MD , Benavides M.P. Polyamines and abiotic stress: Recent advances. Amino Acids 2008; 34: 3545.

Guo B , Zhang Y , Lee H , Du L , Lee Y , Zhang J , Chen S , Zhu Z. The transformation and expression of wheat with Betaine aldehydede hydrogenase (BADH) gene. Chin. Bull Bot. 2000; 42: 279283.

Han SE , Park SR , Kwon HB , Yi BY , Lee GB , Byun M.O. Genetic engineering of drought-resistant tobacco plants by introducing the trehalose phosphorylase (TP) gene from Pleurotussajor-caju. Plant Cell Tissue Organ Cult. 2005; 82: 151158.

Harb A , Krishnam A , Ambavaram MMR , Pereira A. Molecular and physiological analysis of drought stress in Arabidopsis reveals early responses leading to acclimation in plant growth. Plant Physiol. 2010; 154(3): 12541271.

Hare PD , Cress WA , Van Staden J. Dissecting the roles of osmolyte accumulation during stress. Plant Cell Environ. 1998; 21: 535553.

Harinasut P , Tsutsui K , Takabe T , Nomura M , Takabe T , Kishitani S. Exogenous glycinebetaine accumulation and increased salt-tolerance in rice seedlings. Biosci. Biotecha. Biochem. 1996; 60: 366368.

Hasanuzzaman M , Alam MM , Rahman A , Hasanuzzaman M , Nahar K , Fujita M. Exogenous proline and glycinebetaine mediated upregulation of antioxidant defense and glyoxalase 185systems provides better protection against salt-induced oxidative stress in two rice (Oryza sativa L.) varieties. BioMed. Res. Int. 2014; Article ID 757219, 17pp.

Hasegawa PM , Bressan RA , Zhu JK , Bohnert H.J. Plant cellular and molecular responses to high salinity. Annu. Rev. Plant Physiol. Plant Mol. Biol. 2000; 51: 463499.

Hayashi H , Mustardy AL , Deshnium P , Ida M , Murata N. Transformation of Arabidopsis thaliana with the codA gene for choline oxidase: Accumulation of glycine betaine and enhanced tolerance to salt and cold stress. Plant J. 1997; 12: 133142.

Hayashi H , Sakamoto A , Nonaka H. , Chen THH , Murata N. Enhanced germination under high-salt conditions of seeds of transgenic Arabidopsis with a bacterial gene (codA) for choline oxidase. J. Plant Res. 1998; 111: 357362.

Hessine K , Martnez JP , Gandour M , Albouchi A , Soltani A , Abdelly C. Effect of water stress on growth, osmotic adjustment, cell wall elasticity and water use efficiency in Spartina alterniflora. Environ. Exp. Bot. 2009; 67: 312319.

Hincha DK , Hellwege EM , Heyey AG , Crowe J.H. Plant fructans stabilize phosphatidylcholine liposomes during freeze-drying. Eur. J. Biochem. 2000; 267: 535540.

Hincha DK , Zuther E , Hellwege EM , Heyer A.G. Specific effects of fructo- and gluco-oligosaccharides in the preservation of liposomes during drying. Glycobiology 2002; 12: 103110.
Hoekstra FA , Golovina EA , Buitink J. Mechanisms of plant desiccation tolerance. Trends Plant Sci. 2001; 6: 431438.
Holmstrm KO , Mantyla E , Wellin B , Mandal A , Palva E.T. Drought tolerance in tobacco. Nature 1996; 379: 683684.
Holmstrm KO , Somersalo S , Mandal A , Palva TE , Welin B. Improved tolerance to salinity and low temperature in transgenic tobacco producing glycine betaine. J. Exp. Bot. 2000; 51: 177185.
Hong Z , Lakkineni K , Zhang Z , Verma D.P. Removal of feedback inhibition of A1-pyrroline-5-carboxylase synthetase results in increased proline accumulation and protection of plants from osmotic stress. Plant Physiol. 2000; 122: 11291136.
Hoque MA , Banu MN , Okuma E , Amako K , Nakamura Y , Shimoishi Y , Murata Y. Exogenous proline and glycine betaine increases NaCl-induced ascorbate glutathione cycle enzyme activities and proline improves salt tolerance more than glycinebetaine in tobacco Bright yellow-2suspension- cultured cells. J. Plant Physiol. 2007a; 164(11): 14571468.
Hoque MA , Okuma E , Banu MNA , Nakamura Y , Shimoishi Y , Murata Y. Exogenous proline mitigates the detrimental effects of salt stress more than exogenous betaine by increasing antioxidant enzyme activities. J. Plant Physiol. 2007b; 164: 553561.
Huang J , Hirji R , Adam L , Rozwadowski K , Hammerlindl J , Keller W , Selvaraj G. Genetic engineering of glycinebetaine production toward enhancing stress tolerance in plants: Metabolic limitations. Plant Physiol. 2000; 122: 747756.
Hussain M , Malik MA , Farooq M , Ashraf MY , Cheema M.A. Improving drought tolerance by exogenous application of glycinebetaine and salicylic acid in sunflower. J. Agron. Crop Sci. 2008; 194(3): 193199.
Iqbal N , Ashraf MY , Ashraf M. Influence of water stress and exogenous glycinebetaine on sunflower achene weight and oil percentage. Int. J. Sci. Technol. 2005; 2: 155160.
Iqbal N , Ashraf MY , Ashraf M. Influence of exogenous glycine betaine on gas exchange and biomass production in sunflower (Helianthus annuus L.) under water limited conditions. J. Agron. Crop Sci. 2009; 195: 420426.
Iturriaga G , Suarez R , Nova-Franco B. Trehalose metabolism: From osmoprotection to signalling. Int. J. Mol. Sci. 2009; 10: 37933810.
Jaleel CA , Manivannan P , Wahid A , Farooq M , Al-Juburi HJ , Somasundaram R , Panneerselvam R. Drought stress in plants: A review on morphological characteristics and pigments composition. Int. J. Agric. Biol. 2009; 11(1): 100105.
Jang IC , Oh SJ , Seo JS , Choi WB , Song SI , Kim CH , Kim YS , Seo HS , Choi YD , Nahm BH , Kim J.K. Expression of a bifunctional fusion of the Escherichia coli genes for trehalose-6- phosphate synthase and trehalose-6-phosphate phosphatase in transgenic rice plants increases trehalose accumulation and abiotic stress tolerance without stunting growth. Plant Physiol. 2003; 131: 516524.
Jia G , Zhu Z , Chang F , Li Y. Transformation of tomato with the BADH gene from Atriplex improves salt tolerance. Plant Cell Rep. 2002; 21: 141146.
Karim S , Aronsson H , Ericson, H , Pirhonen M , Leyman B , Welin B , Mntyl E , Palva E , Dijck P , Holmstrm K.O. Improved drought tolerance without undesired side effects in transgenic plants producing trehalose. Plant Mol. Biol. 2007; 64: 371386.
Kathuria H , Giri J , Nataraja KN , Murata N , Udayakumar M , Tyagi A. K. Glycine betaine induced water-stress tolerance in codA-expressing transgenic indica rice is associated with up-regulation of sever al stress responsive genes. Plant Biotechnol. J. 2009; 7: 512526.
Kaushik JK , Bhat R. Why is trehalose an exceptional protein stabilizer? An analysis of the thermal stability of proteins in the presence of the compatible osmolyte trehalose. J. Biol. Chem. 2003; 278: 2645826465.
Kaya C , Snmez O , Aydemir S , Dikilita M. Mitigation effects of glycinebetaine on oxidative stress and some key growth parameters of maize exposed to salt stress. Turk. J. Agric. For. 2013; 37: 188194.
Kaya C , Tuna AL , Ashraf M. , Altunlu H. Improved salt tolerance of melon (Cucumis melo L.) by the addition of proline and potassium nitrate. Environ. Exp. Bot. 2007, 60: 397403.
Kendall EJ , Adams RP , Kartha K.K. Trehalase activity in plant tissue cultures. Phytochemistry 1990; 29: 25252528.
Kiani SP , Talia P , Maury P , Grieu P , Heinz R , Perrault A , Nishinakamasu V , Hopp E , Gentzbittel L , Paniego N , Sarrafi A. Genetic analysis of plant water status and osmotic adjustment in recombinant inbred lines of sunflower under two water treatments. Plant Sci. 2007: 172: 773787.
Kishitani S , Watanabe K , Yasuda S , Arakawa K , Takabe T. Accumulation of glycine betaine during cold accumulation and freezing tolerance in leaves of winter and spring barley plants. Plant Cell Environ. 1994; 17: 8995.
Kolbe A , Tiessen A , Schluepmann H , Paul Ulrich MS , Geigenberger P. Trehalose-6-phodphate regulates starch synthesis via post-translation redox activation of ADP-glucose pyrophosphorylase. Proc. Natl. Acad. Sci. USA 2005; 102: 1111811123.
Konstantinova T , Parvanova D , Atanassov A , Djilianov D. Freezing tolerant tobacco, transformed to accumulate osmoprotectants. Plant Sci. 2002; 163: 157164.
Kramer R, Morbach S. BetP of Corynebacterium glutamicum, a transporter with three different functions: Betaine transport, osmosensing, and osmoregulation. Biochim. Biophys. Acta 2004; 1658, 3136.
186 Krasensky J, Jonak C. Drought, salt, and temperature stress-induced metabolic rearrangements and regulatory networks. J. Exp. Bot. 2012; 63(4): 15931608.
Lawlor DW , Cornic G. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. Plant Cell Environ. 2002; 25: 275294.
Lee CB , Hayashi H , Moon B.Y. Stabilization by glycinebetaine of photosynthetic oxygen evolution by thylakoid membranes from Synechococcus PCC7002. Mol. Cells 1997; 7: 296299.
Lee SB , Kwon HB , Kwon SJ , Park SC , Jeong MJ , Han SE , Byun MO , Daniell H. Accumulation of trehalose within transgenic chloroplasts confers drought tolerance. Mol Breed. 2003; 11: 113.
Li S , Li F , Wang J , Zhang W , Meng Q , Chen TH , Murata N , Yang X. Glycine betaine enhances the tolerance of tomato plants to high temperature during germination of seeds and growth of seedlings. Plant Cell Environ. 2011; 34: 19311943.
Lokhande VH, Suprasanna P. Prospects of halophytes in understanding and managing abiotic stress tolerance. In: Ahmad P , Prasad MNV , eds. Environmental Adaptations and Stress Tolerance of Plants in the Era of Climate Change. New York: Springer, 2012; 2956.
Longstreth DJ , Burrow GB , Yu G. Solutes involved in osmotic adjustment to increasing salinity in suspension cells of Alternanthera philoxeroides Griseb. Plant Cell Tissue Organ Cult. 2004; 78: 225230.
Lunn JE , Delorge I , Figueroa CM , Dijck VP , Stitt M. Trehalose metabolism in plants. Plant J. 2014; 79: 544567.
Lunn J , Feil R , Hendriks JHM , Gibon Y , Morcuende R , Osuna D , Scheible WR , Carillo P , Hajirezaei MR , Stitt M. Sugar-induced increases in trehalose6-phosphate are correlated with redox activation of ADP glucose pyrophosphorylase and higher rates of starch synthesis in Arabidopsis thaliana. Biochem. J. 2006; 397: 139148.
Luo Y , Li F , Wang GP , Yang XH , Wang W. Exogenously-supplied trehalose protects thylakoid membranes of winter wheat from heat-induced damage. Biol. Plant 2010; 54: 495501.
Ma QQ , Wang W , Li YH , D. Li , Zou Q.Q. Alleviation of photoinhibition in drought-stressed wheat (Triticum aestivum) by foliar-applied glycinebetaine. J. Plant Physiol. 2006; 163: 165175.
Mahouachi J , Argamasilla R , Gomez-Cadenas A. Influence of exogenous glycinebetaine and abscisic acid on papaya in responses to water-deficit stress. J. Plant Growth Regul. 2012; 31: 110.

Makela P , Jokinen K , Kontturi M , Peltonen-Sainio P , Pehu E , Somersalo S. Foliar application of glycine betaine: A novel product from sugar beet as an approach to increase tomato yield. Ind. Crops Prod. 1998; 7: 139148.

Makela P , Mantila J , Hinkkanen R , Pehu E , Peltonen-Sainio P. Effect of foliar applications of glycine betaine on stress tolerance, growth, and yield of spring cereals and summer turnip rape in Finland. J. Agron. Crop Sci. 1996a; 176(4): 223234.

Makela P , Peltonensainio P , Jokinen K , Pehu E , Setala H , Hinkkanen R , Somersalo S. Uptake and translocation of foliar-applied glycine betaine in crop plants. Plant Sci. 1996b; 121: 221234.

Martinez AT , Speranza M , Ruiz-Dueas FJ , Ferreira P , Camarero S , Guilln F , Martnez MJ , Gutirrez A , Del Ro J.C. Biodegradation of lignocellulosics: Microbial, chemical, and enzymatic aspects of the fungal attack of lignin. Int. Microbiol. 2005; 8: 195204.

Martinez J , Lutts S , Schanck A , Bajji M , Kinet J.M. Is osmotic adjustment required for water stress resistance in the Mediterranean shrub Atriplex halimus L? J. Plant Physiol. 2004; 161: 10411051.

Matsunaga E , Nanto K , Oishi M , Ebinuma H , Morishita Y , Sakurai N , Suzuki H , Shibata D. Agrobacterium-mediated transformation of Eucalyptus globulus using explants with shoot apex with introduction of bacterial choline oxidase gene to enhance salt tolerance. Plant Cell Rep. 2012; 31: 225235.

McCue K , Hanson A. Drought and salt tolerance: Towards understanding and application. Trends Biotechnol. 1990; 8: 358362.

McNeil SD , Nuccio ML , Hanson A.D. Betaines and related osmoprotectants. Targets for metabolic engineering of stress resistance. Plant Physiol. 1999; 120: 945949.

Meek C , Oosterhuis D , Gorham J. Does foliar applied glycine betaine affect endogenous betaine levels and yield in cotton? Crop Manage. 2003. Available online. doi:10.1094/CM-2003-0804-02-RS.

Miranda JA , Avonce N , Surez R , Thevelein JM , Van Dijck P , Iturriaga G. A bifunctional TPSTPP enzyme from yeast confers tolerance to multiple and extreme abiotic-stress conditions in transgenic Arabidopsis. Planta 2007; 226: 14111414.

Miri HR , Armin M. The interaction effect of drought and exogenous application of glycine betaine on corn (Zea mays L.). Eur. J. Exp. Biol. 2013; 3(5): 197206.

Moghaieb REA , Saneoka H , Fujita K. Effect of salinity on osmotic adjustment, glycine betaine accumulation and the betaine aldehyde de hydrogenase gene expression in two halophytic plants, Salicornia europaea and Suaedamaritima. Plant Sci. 2004; 166: 13451349.

Mohanty A , Kathuria H , Ferjani A , Sakamoto A , Mohanty P , Murata N , Tyagi A. Transgenics of an elite indica rice variety Pusa Basmati 1 harbouring the codA gene are highly tolerant to salt stress. Theor. Appl. Genet. 2002; 106: 5157.

Muller J , Aeschbacher RA , Sprenger N , Boller T , Wiemken A. Disaccharide-mediated regulation of sucrose:fructan-6-fructosyltransferase, a key enzyme of fructan synthesis in barley leaves. Plant Physiol. 2000; 123: 265274.

Muller J , Aeschbacher R , Wingler A , Boller T , Wiemken A. Trehalose and trehalase in Arabidopsis. Plant Physiol. 2001; 125: 10861093.

Muller J , Boller T , Wiemkem A. Trehalose and trehalase in plants: recent developments. Plant Sci. 1995a; 112: 19.

Muller J , Boller T , Wiemkem A. Effects of validamycin A, a potent trehalose inhibitor, and phytohormones on trehalose metabolism in roots and root nodules of soybean and cowpea. Planta 1995b; 197: 362368.

Muller J , Boller T , Wiemkem A. Trehalose affects sucrose synthase and invertase activities in soybean (Glycine max [L.] Merr) roots. J. Plant Physiol. 1998; 153: 255257.

Muller J , Wiemken R , Aeschbacher R. Trehalose metabolism in sugar sensing and plant development. Plant Sci. 1999; 147: 3747.

Murata N , Takahashi S , Nishiyama Y , Allakhverdiev S.I. Photoinhibition of photosystem II under environmental stress. Biochim. Biophys. Acta (BBA)-Bioenerg. 2007; 1767: 414421.

Naidu BP , Cameron DF , Konduri S.V. Improving drought tolerance of cotton by glycine betaine application and selection. In: Michalk DL , Pratley JE , eds. Proceedings of the 9th 187Australian Agronomy Conference; Wagga Wagga, Australia. Serpentine, Australia: Australian Society of Agronomy, 2023 July 1998; 15.

Nayyar H , Bains T , Kumar S. Low temperature induced floral abortion in chickpea: Relationship with abscisic acid and cryoprotectants in reproductive organs. Environ. Exp. Bot. 2005; 53: 3947.

Nomura M , Hibino T , Takabe T , Sugiyama T , Yokota A , Miyake H , Takabe T. Transgenically produced glycinebetaine protects ribulose 1,5-bisphosphate carboxylase/oxygenase from inactivation in Synechococcus sp. PCC7942 under salt stress. Plant Cell Physiol. 1998; 39: 425432.

P ark E , Jeknic JZ , Chen T.H. Exogenous application of glycine betaine increases chilling tolerance in tomato plants. Plant Cell Physiol. 2006; 47: 706714.

Park EJ , Jeknic Z , Pino MT , Murata N , Chen T.H. Glycine betaine accumulation is more effective in chloroplasts than in the cytosol for protecting transgenic tomato plants against abiotic stress. Plant Cell Environ. 2007; 30: 9941005.

Parry MAJ , Andralojc PJ , Khan S , Lea PJ , Keys A.J. Rubisco activity: Effects of drought stress. Ann. Bot. 2002; 89: 833839.

Paul M. Trehalose 6-phosphate. Curr. Opin. Plant Biol. 2007; 10: 303309.

Paul M , Pellny T , Goddijn O. Enhancing photosynthesis with sugar signals. Trends Plant Sci. 2001; 6: 197200.

Peel GJ , Mickelbart MV , Rhodes D . Choline metabolism in glycinebetaine accumulating and non-accumulating near-isogenic lines of Zea mays and Sorghum bicolor. Phytochemistry 2010; 71: 404414.

Pellny TK , Ghannoum O , Conroy JP , Schluepmann H , Smeekens S , Andralojc J , Krause KP , Goddijn O , Paul M.J. Genetic modification of photosynthesis with E. coli genes for trehalose synthesis. Plant Biotechnol. 2004; 2: 7182.

Penna S. Building stress tolerance through over-producing trehalose in transgenic plants. Trends Plant Sci. 2003; 8: 355357.

Pilon-Smits Eah , Ebskamp MJM , Paul MJ , Jeuken MJW , Weisbeek PJ , Smeekens S .C.M. Improved performance of transgenic fructan-accumulating tobacco under drought stress. Plant Physiol. 1995; 107: 125130.

Pilon-Smits Eah , Terry N , Sears T , Dun K.V. Enhanced drought resistance in fructan-producing sugar beet. Plant Physiol. Biochem. 1999; 37: 313317.

Pilon-Smits Eah , Terry N , Sears T , Kim H , Zayed A , Hwang S , van Dun, K , Voogd E , Verwoerd TC , Krutwagen RH , Goddijn O.J. Trehalose-producing transgenic tobacco plants show improved growth performance under drought stress. J. Plant Physiol. 1998; 152: 525532.

Prasad Kvsk , Sharmila P , Kumar PA , Saradhi P. Transformation of Brassica juncea (L.) Czern with a bacterial codA gene enhances its tolerance to salt stress. Mol. Breed. 2000; 6: 489499.

Quan R , Shang M , Zhang H , Zhao Y , Zhang J. Engineering of enhanced glycine betaine synthesis improves drought tolerance in maize. Plant Biotechnol. J. 2004; 2: 477486.

Ramakrishna A , Ravishankar G.A. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal. Behav. 2011; 6: 17201731.

Ramakrishna A , Ravishankar G.A. Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Tuteja N , Gill SS , eds. Climate Change and Abiotic Stress Tolerance. Weinheim: Wiley-VCH, 2013. ISBN 978-3-527-33491-9.

Rathinasabapathi B. Metabolic engineering for stress tolerance: Installing osmoprotectant synthesis pathways. Ann. Bot. 2000; 86(4): 709716.

Raymond MJ , Smirnoff N. Proline metabolism and transport in maize seedlings at low water potential. Ann Bot. 2002; 89: 813823.
Raza MAS , Saleem MF , Shah GM , Khan IH , Raza A. Exogenous application of glycinebetaine and potassium for improving water relations and grain yield of wheat under drought. J. Soil Sci. Plant Nutr. 2014; 14(2): 348364.
Raza SH , Athar HR , Ashraf M , Hameed A. Glycine betaine induced modulation of antioxidant enzymes activities and ion accumulation in two wheat cultivars differing in salt tolerance. Environ. Exp Bot. 2007; 60: 368376.
Reddy KR , Seepaul R , Henry WB , Gajanayake B , Lokhande S , Brand D. Maize (Zea mays L.) yield and aflatoxin accumulation responses to exogenous glycinebetaine application. Int. J. Plant Prod. 2014; 8(2): 271290.
Rezaei MA , Kaviani B , Masouleh A.K. The effect of exogenous glycine betaine on yield of soybean [Glycine max (L.) Merr.] in two contrasting cultivars Pershing and DPX under soil salinity stress. Plant Omics J. 2012; 5(2): 8793.
Rhodes D , Hanson A.D. Quaternary ammonium and tertiary sulfonium compounds in higher plants. Annu. Rev. Plant Physiol. Plant Mol. Biol. 1993; 44: 357384.
Rhodes D , Rich P.J. Preliminary genetic studies of the phenotype of betaine deficiency in Zea mays L. Plant Physiol. 1988; 88(1): 102108.
Richards AB , Krakowka S , Dexter LB , Schmid H. Wolterbeek APM, Waalkens-Berendsen DH, Shigoyuki M, Kurimoto AM. Trehalose: A review of properties, history of use and human tolerance, and results of multiple safety studies. Food Chem. Toxicol. 2002; 40: 871898.
Rodriguez FR , Mellor RB , Arias C , Cabriales P.J.J. The accumulation of trehalose in nodules of several cultivars of commo n bean (Phaseolus vulgaris) and its correlation with resistance to drought stress. Physiol Plant. 1998; 102: 353359.
Rolland F , Moore B , Heen S.J. Sugar sensing and signaling in plants. Plant Cell 2002; 14(Suppl. 1): S185S205.
Romero C , Belles JM , Vaya JL , Serrano R , Culianez-Macia F.A. Expression of the yeast trehalose-6-phosphate synthase gene in transgenic tobacco plants: Pleiotropic phenotypes include drought tolerance. Planta 1997; 201: 293297.
Sakamoto A , Alia RV , Chen THH , Murata N. Transformation of Arabidopsis with the codA gene for choline oxidase enhances freezing tolerance of plants. Plant J. 2000; 22(5): 449453.
Sakamoto A , Murata N. Genetic engineering of glycine-betaine synthesis in plants: Current status and implications for enhancement of stress tolerance. J. Exp. Bot. 2000; 51: 8188.
Sakamoto A , Murata N. The role of glycine betaine in the protection of plants from stress: Clues from transgenic plants. Plant Cell Environ. 2002; 25: 163171.
Saneoka H , Ishiguro S , Moghaieb R.E. Effect of salinity and abscisic acid on accumulation of glycine betaine and betaine aldehyde dehydrogenase mRNA in sorghum leaves (Sorghum bicolor). J. Plant Physiol. 2001; 158: 853859.
188 Saneoka H , Nagasaka C , Hahn DT , Yang WJ , Premachandra GS , Joly RJ , Rhodes D. Salt tolerance of glycinebetaine-deficient and -containing maize lines. Plant Physiol. 1995; 107: 631638.
Satoh-Nagasawa N , Nagasawa N , Malcomber S , Sakai H , Jackson D. A trehalose metabolic enzyme controls inflorescence architecture in maize. Nature 2006; 441: 227230.
Schluepmann H , Pellny T , van Dikken A , Smeekens S , Paul M. Trehalose 6-phosphate is indispensable for carbohydrate utilization and growth in Arabidopsis thaliana. Proc. Natl. Acad. Sci. USA. 2004a; 100(11): 68496854.
Schluepmann H , Van Dikken A , Aghdasi M , Wobbes B , Paul M , Smeekens S. Trehalose mediated growth inhibition of Arabidopsis seedlings is due to trehalose-6-phosphate accumulation. Plant Physiol. 2004b; 135: 879890.
Serraj R , Sinclair T.R. Osmolyte accumulation: Can it really help increase crop yield under drought conditions? Plant Cell Environ. 2002; 25: 333341.
Shabala L , Mackay A , Tian Y , Jacobsen SE , Zhou D , Shabala S. Oxidative stress protection and stomatal patterning as components of salinity tolerance mechanism in quinoa (Chenopodium quinoa). Physiol. Plant 2012; 146: 2638.
Shahbaz M , Masood Y , Parveen S , Ashraf M. Is foliar applied glycinebetaine effective in mitigating the adverse effects of drought stress on wheat (Triticum aestivum L.)? J. Appl. Bot. Food Tech. 2011; 84: 192199.
Shen B , Jensen RG , Bohnert H.J. Mannitol protects against oxidation by hydroxyl radicals. Plant Physiol. 1997; 115: 527532.
Siopongco J , Sekiya K , Yamauchi A , Egdane J , Ismail AM , Wade L.J. Stomatal responses in rainfed lowland rice to partial soil drying; comparison of two lines. Plant Prod. Sci. 2009; 12: 1728.
Smirnoff N, Cumbes Q.J. Hydroxyl radical scavenging activity of compatible solutes. Phytochemistry 1989; 28: 10571060.
Smith SE , Smith F.A. Uptake of glucose, trehalose and mannitol by leaf slices of the orchid Bletilla hyacinthina. New Phytol. 1973; 72: 957964.
Sola-Penna M, Meyer-Fernandes J.R. Stabilization against thermal inactivation promoted by sugars on enzyme structure and function: Why is trehalose more effective than other sugars? Arch. Biochem. Biophys. 1998; 360: 1014.
Solomon A , Beer S , Waisel Y , Jones GP , Paleg L.G. Effects of NaCl on the carboxylating activity of Rubisco from Tamarix jordanis in the presence and absence of proline- water stress related compatible solutes. Plant Physiol. 1994; 90: 198204.
Stepien P, Klobus G. Antioxidant defense in the leaves of C3 and C4 plants under salinity stress. Physiol. Plant 2005; 125: 3140.
Su J , Hirji R , Zhang L , He C , Selvaraj G , Wu R. Evaluation of the stress-inducible production of choline oxidase in transgenic rice as a strategy for producing the stress-protectant glycine betaine. J. Exp. Bot. 2006; 57: 11291135.
Suarez R , Calderon C , Iturriaga G. Improved tolerance to multiple abiotic stresses in transgenic alfalfa accumulating trehalose. Crop Sci. 2009; 49: 17911799.
Subbarao GV , Wheeler RM , Levine LH , Stutte G.W. Glycine betaine accumulation, ionic and water relations of red-beet at contrasting levels of sodium supply. J. Plant Physiol. 2001; 158: 767776.
Sulpice R , Tsukaya H , Nonaka H , Mustardy L , Chen T , Murata N. Enhanced formation of flowers in salt stressed Arabidopsis after genetic engineering of the synthesis of glycine betaine. Plant J. 2003; 36: 165176.
Taize L , Zeiger E. Plant Physiology, 4th ed. Sunderland, MA: Sinauer Associates, Inc., 2006.
Takabe T , Rai V , Hibino T. Osmotic stresses; Metabolic engineering of glycinebetaine. Section V: P.135. In: Rai AK , Takabe T , eds. Abiotic Stress Tolerance in Plants Toward the Improvement of Global Environment and Food. Dordrecht, the Netherlands: Springer, 2005.
Takahashi S , Murata N. How do environmental stresses accelerate photoinhibition? Trends Plant Sci. 2008; 13: 178182.
Van Dijken A , Schluepmann H , Smeekens S.C.M. Arabidopsis trehalose-6-phosphate synthase 1 is essential for normal vegetative growth and transition to flowering. Plant Physiol. 2004; 135: 969977.
Veluthambi K , Mahadevan S , Maheshwari R. Trehalose toxicity in Cuscuta reflexa. Plant Physiol. 1981; 68: 13691374.
Vinocur B , Altman A. Recent advances in engineering plant tolerance to abiotic stress: Achievements and limitations. Curr. Opin. Biotechnol. 2005; 16(2): 123132.
Vogel G , Fiehn O , Jean-Richard-dit-Bressel L , Boller T , Wiekem A , Aeschbacher RA , Wingler A. Trehalose metabolism in Arabidopsis: Occurrence of trehalose and molecular cloning and characterization of trehalose-6-phosphate synthase homologues. J. Exp. Bot. 2001; 52: 18171826.
Waditee R , Bhuiyan M , Nazmul H , Rai V , Aoki K , Tanaka Y , Hibino T , Suzuki S , Takano J , Jagendorf A . Genes for direct methylation of glycine provide high levels of glycinebetaine and abiotic-stress tolerance in Synechococcus and Arabidopsis. Proc Natl Acad Sci. 2005; 102: 1318.

Wagner W , Wiemken A , Matile P. Regulation of fructan metabolism in leaves of barley (Hordeumvulgare L. Cv. Gerbel). Plant Physiol. 1986; 81: 444447.
Wahid A , Gelani S , Ashraf M , Foolad M.R. Heat tolerance in plants: An overview. Environ. Exp. Bot. 2007; 61: 199223.
Wang GP , Hui Z , Li F , Zhao MR , Zhang J , Wang W. Improvement of heat and drought on photosynthetic tolerance in wheat by accumulation of glycine betaine. Plant Biotech. Rep. 2010a; 4: 212222.
Wang GP , Zhang XY , Li F , Luo Y , Wang W. Over accumulation of glycine betaine enhances tolerance to drought and heat stress in wheat leaves in the protection of photosynthesis. Photosynthetica 2010b; 48: 117 126.
Wang YM , Meng YL , Nii N. Changes in glycine betaine and related enzyme contents in Amaranthus tricolor under salt stress. J. Plant Physiol. Molbiol. 2004; 30(5): 496502.
Wang Z , Zhang S , Yang B , Li Y. Trehalose synthase gene transfer mediated by Agrobacterium tumefaciens enhances resistance to osmotic stress in sugarcane. Sugar Tech. 2005; 7: 4954.
Willmitzer L , Heyer A , Kossmann J. Production of new or modified carbohydrates in transgenic plants. Proceedings of the 5th Symposium on Renewable Resources, 1997.
Wingler A , Fritzius T , Wiemken A , Boller T , Aeschbacher R. Trehalose induces the ADP-glucose pyrophosphorylase gene, ApL3, and starch synthesis in Arabidopsis. Plant Physiol. 2000; 124: 105114.
Xing W , Rajashekar C.B. Alleviation of water stress in beans by exogenous glycine betaine. Plant Sci. 1999; 148: 185195.
Xing W , Rajashekar C.B. Glycine betaine involvement in freezing tolerance and water stress in Arabidopsis thaliana. Environ. Exp. Bot. 2001; 46: 2128.
Yancey P.H. Organic osmolytes as compatible, metabolic and counteracting cytoprotectants in high osmolarity and other stresses. J. Exp. Biol. 2005; 208(Pt 15): 28192830.
189 Yang X , Lu C. Photosynthesis is improved by exogenous glycine betaine in salt-stressed maize plants. Physiol Plant. 2005; 124(3): 343352.
Yang X , Lu C. Effects of exogenous glycine betaine on growth, CO2 assimilation, and photosystem II photochemistry of maize plants. Physiol Plant. 2006; 127(4): 593602.
Yang XH , Liang Z , Lu C.M. Genetic engineering of the biosynthesis of glycine betaine enhances photosynthesis against high temperature stress in transgenic tobacco plants. Plant Physiol. 2005; 138: 22992309.
Yang XH , Wen XG , Gong HM , Lu QT , Yang ZP , Tang YL , Liang Z , Lu C.M. Genetic engineering of the biosynthesis of glycine betaine enhances thermo tolerance of photosystem II in tobacco plants. Planta 2007; 225: 719733.
Yeo ET , Kwon HB , Han SE , Lee JT , Ryu JC , Byu M.O. Genetic engineering of drought resistant potato plants by introduction of the trehalose-6-phosphate synthase (TPS1) gene from Saccharomyces cerevisiae. Mol Cell. 2000; 30: 263268.
Yuanyuan M , Yali Z , Jiang L , Hongbo S. Roles of plant soluble sugars and their responses to plant cold stress. Afr. J. Biotech. 2009; 8: 20042010.
Zeid I.M. Trehalose as osmoprotectant for maize under salinity-induced stress. Res. J. Agric. Biol. Sci. 2009; 5(5): 613622.
Zentella R , Mascorro-Gallardo JO , Van Dijck P , Folch-Mallol J , Bonini B , Van Vaeck C , Gaxiola R , Covarrubias AA , Nieto-Sotelo J , Thevelein JM , Iturriaga G. A Selaginella lepidophylla trehalose-6-phosphate synthase complements growth and stress-tolerance defects in a yeast tps1 mutant. Plant Physiol. 1999; 119(4): 14731482.
Zhang H , Zhang S , Yang J , Zhang J , Wang Z. Postanthesis moderate wetting drying improves both quality and quantity of rice yield. Agron. J. 2008; 100: 726734.
Zhang LX , Li SX , Liang Z.S. Differential plant growth and osmotic effects of two maize (Zea mays L.) cultivars to exogenous glycinebetaine application under drought stress. Plant Growth Regul. 2009b; 8: 297305.
Zhang N , Ci H , Li L , Yang T , Zhang C , Wang D. Enhanced drought tolerance of potato with introduced BADH gene. Acta Agron. Sin. 2009a; 35: 11461150.
Zhao XX , Ma QQ , Liang C , Fang Y , Wang YQ , Wang W. Effect of Glycine betaine on function of thylakoid membranes in wheat flag leaves under drought stress. Biol. Plant 2007; 51: 584588.
Zhao Z , Chen G , Zhang C. Interaction between reactive oxygen species and nitric oxide in drought-induced abscisic acid synthesis in root tips of wheat seedlings. Aust. J. Plant Physiol. 2001; 28: 10551061.
Zhonghua Ch , Tracey A , Cuin M , Amanda T , Bodapati P , Shabala S. Compatible solute accumulation and stress- mitigating effects in barley genotypes contrasting in their salt tolerance. J. Exp. Bot. 2007; 58(15/16): 42454255.
Zhou S , Chen X , Zhang X , Li Y. Improved salt tolerance in tobacco plants by co-transformation of a betaine synthesis gene BADH and a vacuolar Na+/H+ antiporter gene SeNHX1. Biotechnol. Lett. 2008; 30: 369376.
Zhu MY , Ahn SJ , Matsumoto H. Inhibition of growth and development of root border cells by Al. Physiol. Plant. 2003; 117: 359367.

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Ackerson R.C. 1981. Osmoregulation in cotton in response to water stress II. Leaf carbohydrate status in relation to osmotic adjustment. Plant Physiol. 67: 489493.
Aikens D , Bunge S , Onasch F , Parker R , Hurwitz C , Clemans S. 1983. The interactions between nucleic acids and polyamines. Biophys. Chem. 17: 6774.
Alczar R , Altabella T , Marco F , Bortolotti C , Reymond M , Koncz C , Carrasco P , Tiburcio A.F. 2010a. Polyamines: molecules with regulatory functions in plant abiotic stress tolerance. Planta 231: 12371249.
Alczar R , Bitrin M , Bartels D , Koncz C , Altabella T , Tiburcio A.F. 2011. Polyamine metabolic canalization in response to drought stress in Arabidopsis and the resurrection plant Craterostigma plantagineum. Plant Signal. Behav. 6: 243250.
Alczar R , Cuevas JC , Patron M , Altabella T , Tiburcio A.F. 2006a. Abscisic acid modulates polyamine metabolism under water stress in Arabidopsis thaliana. Physiol. Plantarum 128: 448455.
Alczar R , Marco F , Cuevas JC , Patron M , Ferrando A , Carrasco P , Tiburcio AF , Altabella T. 2006b. Involvement of polyamines in plant response to abiotic stress. Biotechn. Lett. 28: 18671876.
Alczar R , Planas J , Saxena T , Zarza X , Bortolotti C , Cuevas J , Bitrin M , Tiburcio AF , Altabella T. 2010b. Putrescine accumulation confers drought tolerance in transgenic Arabidopsis plants over-expressing the homologous ARGININE DECARBOXYLASE 2 gene. Plant Physiol. Biochem. 48: 547552.
Alet AI , Snchez DH , Cuevas JC , Marina M , Carrasco P , Altabella T , Tiburcio AF , Ruiz O.A. 2012. New insights into the role of spermine in Arabidopsis thaliana under long-term salt stress. Plant Sci. 182: 94100.
Alet AI , Snchez DH , Ferrando A , Tiburcio AF , Alcazar R , Cuevas JC , Altabella T , et al. 2011. Homeostatic control of polyamine levels under long-term salt stress in Arabidopsis. Plant Signal. Behav. 6: 237242.

An Z , Jing W , Liu Y , Zhang W. 2008. Hydrogen peroxide generated by copper amine oxidase is involved in abscisic acid-induced stomatal closure in Vicia faba. J. Exp. Bot. 59: 815825.

Anwar R , Mattoo AK , Handa A.K. 2015. Polyamine interactions with plant hormones: Crosstalk at several levels. In: Kusano T , Suzuki H (eds.). Polyamines, pp. 267302. Springer, Japan, Tokyo.

Bachrach U. 2010. The early history of polyamine research. Plant Physiol. Biochem. 48: 490495.

Bitrin M , Zarza X , Altabella T , Tiburcio AF , Alczar R. 2012. Polyamines under abiotic stress: metabolic crossroads and hormonal crosstalks in plants. Metabolites 2: 516528.

Brggemann LI , Pottosin II , Schnknecht G. 1998. Cytoplasmic polyamines block the fast-activating vacuolar cation channel. Plant J. 16: 101105.

Capell T , Bassie L , Christou P . 2004. Modulation of the polyamine biosynthetic pathway in transgenic rice confers tolerance to drought stress. Proc. Nat. Acad. Sci. USA 101: 99099914.

Casero RA , Marton L.J. 2007. Targeting polyamine metabolism and function in cancer and other hyperproliferative diseases. Nat. Rev. Drug Discovery 6: 373390.

Chang KS , Lee SH , Hwang SB , Park K.Y. 2000. Characterization and translational regulation of the arginine decarboxylase gene in carnation (Dianthus caryophyllus L.). Plant J. 24: 4556.

Chattopadhayay MK , Tiwari BS , Chattopadhyay G , Bose A , Sengupta DN , Ghosh B. 2002. Protective role of exogenous polyamines on salinity-stressed rice (Oryza sativa) plants. Physiol. Plantarum 116: 192199.

Cheng L , Sun R , Wang F , Peng Z , Kong F , Wu J , Cao J , Lu G. 2012. Spermidine affects the transcriptome responses to high temperature stress in ripening tomato fruit. J. Zhejiang Univ. Sci. B 13: 283297.

Crawford N.M. 2006. Mechanisms for nitric oxide synthesis in plants. J. Exp. Bot. 57: 471478.

Cuevas JC , Lpez-Cobollo R , Alczar R , Zarza X , Koncz C , Altabella T , Salinas J , Tiburcio AF , Ferrando A. 2008. Putrescine is involved in Arabidopsis freezing tolerance and cold acclimation by regulating abscisic acid levels in response to low temperature. Plant Physiol. 148: 10941105.

Do PT , Degenkolbe T , Erban A , Heyer AG , Kopka J , Khl KI , Hincha DK , Zuther E. 2013. Dissecting rice polyamine metabolism under controlled long-term drought stress. PLoS One 8: e60325.

199 Do PT , Drechsel O , Heyer AG , Hincha DK , Zuther E. 2014. Changes in free polyamine levels, expression of polyamine biosynthesis genes, and performance of rice cultivars under salt stress: A comparison with responses to drought. Front. Plant Sci. 5: 182. doi doi 10.3389/fpls.2014.00182.

Dong S , Hu H , Wang Y , Xu Z , Zha Y , Cai X , Peng L , Feng S . 2016. A pqr2 mutant encodes a defective polyamine transporter and is negatively affected by ABA for paraquat resistance in Arabidopsis thaliana. J. Plant Res. 129: 899907.

Edwards D , Oldroyd G , Chunthaburee S , Sanitchon J , Pattanagul W , Theerakulpisut P. 2015. Agriculture and climate changeAdapting crops to increased uncertainty (AGRI 2015) Application of exogenous spermidine (Spd) improved salt tolerance of rice at the seedling and reproductive stages. Proc. Environ. Sci. 29: 134.

Espasandin FD , Maiale SJ , Calzadilla P , Ruiz OA , Sansberro P.A. 2014. Transcriptional regulation of 9-CIS-EPOXYCAROTENOID DIOXYGENASE (NCED) gene by putrescine accumulation positively modulates ABA synthesis and drought tolerance in Lotus tenuis plants. Plant Physiol. Biochem. 76: 2935.

Fariduddin Q , Varshney P , Yusuf M , Ahmad A. 2013. Polyamines: potent modulators of plant responses to stress. J. Plant Interact. 8: 116.

Food and Agriculture Administration of the United Nations (FAO). 2009. How to feed the world in 2050. Available online at: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf. Accessed 11/05/2015.

Fujita M , Fujita Y , Iuchi S , Yamada K , Kobayashi Y , Urano K , Kobayashi M , Yamaguchi-Shinozaki K , Shinozaki K . 2012. Natural variation in a polyamine transporter determines paraquat tolerance in Arabidopsis. Proc. Nat. Acad. Sci. USA 109: 63436347.

Fujita M , Shinozaki K. 2014. Identification of polyamine transporters in plants: paraquat transport provides crucial clues. Plant Cell Physiol. 55: 855861.

Ge C , Cui X , Wang Y , Hu Y , Fu Z , Zhang D , Cheng Z , Li J. 2006. BUD2, encoding an S-adenosylmethionine decarboxylase, is required for Arabidopsis growth and development. Cell Res. 16: 446456.

Geny L , Broquedis M , Martin-Tanguy J , Bouard J. 1997. Free, conjugated, and wall-bound polyamines in various organs of fruiting cuttings of Vitis vinifera L. cv. cabernet sauvignon. Am. J. Enol. Vit. 48: 8084.

Ghuge SA , Tisi A , Carucci A , Rodrigues-Pousada RA , Franchi S , Tavladoraki P , Angelini R , Cona A. 2015. Cell wall amine oxidases: new players in root xylem differentiation under stress conditions. Plants 4: 489504.

Groppa MD , Benavides M.P. 2007. Polyamines and abiotic stress: recent advances. Amino Acids 34: 3545.

Gupta K , Dey A , Gupta B. 2013. Plant polyamines in abiotic stress responses. Acta Physiol. Plantarum 35: 20152036.

Hanfrey C , Sommer S , Mayer MJ , Burtin D , Michael A.J. 2001. Arabidopsis polyamine biosynthesis: absence of ornithine decarboxylase and the mechanism of arginine decarboxylase activity. Plant J. 27: 551560.

Janicka-Russak M , Kabaa K , Modziska E , Kobus G. 2010. The role of polyamines in the regulation of the plasma membrane and the tonoplast proton pumps under salt stress. J. Plant Physiol. 167: 261269.

Janowitz T , Kneifel H , Piotrowski M. 2003. Identification and characterization of plant agmatine iminohydrolase, the last missing link in polyamine biosynthesis of plants. FEBS Lett. 544: 258261.

Jorgensen RA , Dorantes-Acosta A.E. 2012. Conserved peptide upstream open reading frames are associated with regulatory genes in angiosperms. Plant Genet. Genom. 3: 191.

Kar R.K. 2015. Interactive role of polyamines and reactive oxygen species in stress tolerance of plants. In: Chakraborty U , Chakraborty B (eds.). Abiotic Stresses in Crop Plants, pp. 212221. CABI, Wallingford.

Kasukabe Y , He L , Nada K , Misawa S , Ihara I , Tachibana S. 2004. Overexpression of Spermidine Synthase enhances tolerance to multiple environmental stresses and up-regulates the expression of various stress-regulated genes in transgenic Arabidopsis thaliana. Plant Cell Physiol. 45: 712722.

Kwak S-H , Lee S.H. 2001. The regulation of Ornithine Decarboxylase gene expression by sucrose and small upstream open reading frame in tomato (Lycopersicon esculentum Mill). Plant Cell Physiol. 42: 314323.

Legocka J , Kluk A. 2005. Effect of salt and osmotic stress on changes in polyamine content and arginine decarboxylase activity in Lupinus luteus seedlings. J. Plant Physiol. 162: 662668.

Li J , Mu J , Bai J , Fu F , Zou T , An F , Zhang J , et al. 2013. PARAQUAT RESISTANT1, a Golgi-localized putative transporter protein, is involved in intracellular transport of paraquat. Plant Physiol. 162: 470483.

Li Z , Jing W , Peng Y , Zhang XQ , Ma X , Huang LK , Yan Y. 2015. Spermine alleviates drought stress in white clover with different resistance by influencing carbohydrate metabolism and dehydrins synthesis. PLoS One 10: e0120708.

Li Z , Zhang Y , Xu Y , Zhang X , Peng Y , Ma X , Huang L , Yan Y. 2016. Physiological and iTRAQ-based proteomic analyses reveal the function of spermidine on improving drought tolerance in white clover. J. Prot. Res. 15: 15631579.

Liu H , Weisman D , Tang L , Tan L , Zhang W , Wang Z , Huang Y , Lin W , Liu X , Coln-Carmona A. 2014. Stress signaling in response to polycyclic aromatic hydrocarbon exposure in Arabidopsis thaliana involves a nucleoside diphosphate kinase, NDPK-3. Planta 241: 95107.

Liu K , Fu H , Bei Q , Luan S. 2000. Inward potassium channel in guard cells as a target for polyamine regulation of stomatal movements. Plant Physiol. 124: 13151326.

Liu M , Chu M , Ding Y , Wang S , Liu Z , Tang S , Ding C , Li G. 2015. Exogenous spermidine alleviates oxidative damage and reduce yield loss in rice submerged at tillering stage. Front. Plant Sci. 6: 919. doi doi 10.3389/fpls.2015.00919.

Maiale S , Snchez DH , Guirado A , Vidal A , Ruiz O.A. 2004. Spermine accumulation under salt stress. J. Plant Physiol. 161: 3542.

Manning DAC. 2015. How will minerals feed the world in 2050? Proc. Geol. Assoc. 126: 1417.

Marco F , Alczar R , Altabella T , Carrasco P , Gill SS , Tuteja N , Tiburcio A.F. 2012. Polyamines in developing stress-resistant crops. In: Tuteja N , Gill SS , Tiburcio AF , Tuteja R (eds.). Improving Crop Resistance to Abiotic Stress, pp. 623635. Wiley-VCH Verlag GmbH & Co. KGaA, Weinhem.

Martin-Tanguy J. 1997. Conjugated polyamines and reproductive development: biochemical, molecular and physiological approaches. Physiol. Plantarum 100: 675688.

200 Mellidou I , Moschou PN , Ioannidis NE , Pankou C , Gmes K , Valassakis C , Andronis EA , et al. 2016. Silencing S-Adenosyl-L-Methionine Decarboxylase (SAMDC) in Nicotiana tabacum points at a polyamine-dependent trade- off between growth and tolerance responses. Front. Plant Sci. 7: 379. doi doi 10.3389/fpls.2016.00379.

Moschou PN , Roubelakis-Angelakis K.A. 2013. Polyamines and programmed cell death. J. Exp. Bot. 65: 12851296; ert373.

Mulangi V , Chibucos MC , Phuntumart V , Morris P.F. 2012. Kinetic and phylogenetic analysis of plant polyamine uptake transporters. Planta 236: 12611273.

Mulangi V , Phuntumart V , Aouida M , Ramotar D , Morris P. 2011. Functional analysis of OsPUT1, a rice polyamine uptake transporter. Planta 235: 111.

Neill S , Barros R , Bright J , Desikan R , Hancock J , Harrison J , Morris P , Ribeiro D , Wilson I. 2008. Nitric oxide, stomatal closure, and abiotic stress. J. Exp. Bot. 59: 165176.

Neily MH , Matsukura C , Maucourt M , Bernillon S , Deborde C , Moing A , Yin Y-G , et al. 2011. Enhanced polyamine accumulation alters carotenoid metabolism at the transcriptional level in tomato fruit over-expressing spermidine synthase. J. Plant Physiol. 168: 242252.

Paoletti P. 1984. Thermochemistry of metal-polyamine complexes. In: Silva MAVR da (ed.). Thermochemistry and Its Applications to Chemical and Biochemical Systems, pp. 339352. Springer, Netherlands.

Pegg AE , Michael A.J. 2010. Spermine synthase. Cel. Mol. Life Sci. 67: 113.

Perez-Amador MA , Leon J , Green PJ , Carbonell J. 2002. Induction of the arginine decarboxylase ADC2 gene provides evidence for the involvement of polyamines in the wound response in Arabidopsis. Plant Physiol. 130: 14541463.

Pospil P , Prasad A. 2014. Formation of singlet oxygen and protection against its oxidative damage in Photosystem II under abiotic stress. J. Photochem. Photobiol. B, Biol. 137: 3948.

Puyang X , An M , Xu L , Han L , Zhang X. 2016. Protective effect of exogenous spermidine on ion and polyamine metabolism in Kentucky bluegrass under salinity stress. Hort. Environ. Biotechnol. 57: 1119.

Rady MM , Hemida K.A. 2015. Modulation of cadmium toxicity and enhancing cadmium-tolerance in wheat seedlings by exogenous application of polyamines. Ecotox. Environ. Saf. 119: 178185.

Ramakrishna A , Ravishankar G.A. 2011. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal. Behav. 6: 17201731.

Ramakrishna A , Ravishankar G.A. 2013. Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Climate Change and Plant Abiotic Stress Tolerance, pp. 705726. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim.

Ramesh SA , Tyerman SD , Xu B , Bose J , Kaur S , Conn V , Domingos P , et al. 2015. GABA signalling modulates plant growth by directly regulating the activity of plant-specific anion transporters. Nat. Comm. 6: 7879.

Rosales EP , Iannone MF , Groppa MD , Benavides M.P. 2011. Polyamines modulate nitrate reductase activity in wheat leaves: involvement of nitric oxide. Amino Acids 42: 857865.

Rosenheim O. 1924. The isolation of spermine phosphate from semen and testis. Biochem. J. 18: 12531262.

Roy P , Niyogi K , SenGupta DN , Ghosh B. 2005. Spermidine treatment to rice seedlings recovers salinity stress-induced damage of plasma membrane and PM-bound H+-ATPase in salt-tolerant and salt-sensitive rice cultivars. Plant Sci. 168: 583591.

Sagor GHM , Zhang S , Kojima S , Simm S , Berberich T , Kusano T. 2016. Reducing cytoplasmic polyamine oxidase activity in arabidopsis increases salt and drought tolerance by reducing reactive oxygen species production and increasing defense gene expression. Plant Physiol. 7: 214.

Snchez-Rodrguez E , Romero L , Ruiz J.M. 2016. Accumulation of free polyamines enhances the antioxidant response in fruits of grafted tomato plants under water stress. J. Plant Physiol. 190: 7278.

Shabala S , Pottosin I. 2014. Regulation of potassium transport in plants under hostile conditions: implications for abiotic and biotic stress tolerance. Physiol. Plantarum 151: 257279.

Sharma YK , Lon J , Raskin I , Davis K.R. 1996. Ozone-induced responses in Arabidopsis thaliana: the role of salicylic acid in the accumulation of defense-related transcripts and induced resistance. Proc. Nat. Acad. Sci. USA 93: 50995104.

Shi H , Ye T , Chan Z. 2013. Comparative proteomic and physiological analyses reveal the protective effect of exogenous polyamines in the bermudagrass (Cynodon dactylon) response to salt and drought stresses. J. Proteome Res. 12: 49514964.

Shi K , Huang YY , Xia XJ , Zhang YL , Zhou YH , Yu J.Q. 2008. Protective role of putrescine against salt stress is partially related to the improvement of water relation and nutritional imbalance in cucumber. J. Plant Nutr. 31: 18201831.

Tanou G , Ziogas V , Belghazi M , Christou A , Filippou P , Job D , Fotopoulos V , Molassiotis A. 2014. Polyamines reprogram oxidative and nitrosative status and the proteome of citrus plants exposed to salinity stress. Plant Cell Environ. 37: 864885.

Tavladoraki P , Cona A , Federico R , Tempera G , Viceconte N , Saccoccio S , Battaglia V , Toninello A , Agostinelli E. 2011. Polyamine catabolism: target for antiproliferative therapies in animals and stress tolerance strategies in plants. Amino Acids 42: 411426.

Tiburcio AF , Altabella T , Bitrin M , Alczar R. 2014. The roles of polyamines during the lifespan of plants: from development to stress. Planta 240: 118.

Tun NN , Santa-Catarina C , Begum T , Silveira V , Handro W , Floh EIS , Scherer G.F.E. 2006. Polyamines induce rapid biosynthesis of nitric oxide (NO) in Arabidopsis thaliana seedlings. Plant Cell Physiol. 47: 346354.

Urano K , Yoshiba Y , Nanjo T , Ito T , Yamaguchi-Shinozaki K , Shinozaki K . 2004. Arabidopsis stress-inducible gene for arginine decarboxylase AtADC2 is required for accumulation of putrescine in salt tolerance. Biochem. Biophys. Res. Comm. 313: 369375.

van Leeuwenhoek A. 1678. Observationes D. Anthonii Leeuwenhoek, de natis e semine genitali animalculis. Philos. Trans. R. Soc. Lond. 12: 10401043.

Venkiteswaran S , Vijayanathan V , Shirahata A , Thomas T , Thomas T.J. 2005. Antisense Recognition of the HER-2 mRNA: Effects of Phosphorothioate Substitution and Polyamines on DNARNA, RNARNA, and DNADNA Duplex Stability. Biochemistry 44: 303312.

Walters D.R. 2000. Polyamines in plantmicrobe interactions. Physiol. Mol. Plant Pathol. 57: 137146.

201 Wang Y , Luo Z , Mao L , Ying T. 2016. Contribution of polyamines metabolism and GABA shunt to chilling tolerance induced by nitric oxide in cold-stored banana fruit. Food Chem. 197, Part A: 333A: 339.

Wi SJ , Kim SJ , Kim WT , Park K.Y. 2014. Constitutive S-adenosylmethionine decarboxylase gene expression increases drought tolerance through inhibition of reactive oxygen species accumulation in Arabidopsis. Planta 239: 979988.

Yamaguchi K , Takahashi Y , Berberich T , Imai A , Miyazaki A , Takahashi T , Michael A , Kusano T. 2006. The polyamine spermine protects against high salt stress in Arabidopsis thaliana. FEBS Lett. 580: 67836788.

Yamaguchi K , Takahashi Y , Berberich T , Imai A , Takahashi T , Michael AJ , Kusano T. 2007. A protective role for the polyamine spermine against drought stress in Arabidopsis. Biochem. Biophys. Res. Comm. 352: 486490.

Yin ZP , Li S , Ren J , Song X.S. 2014. Role of spermidine and spermine in alleviation of drought-induced oxidative stress and photosynthetic inhibition in Chinese dwarf cherry (Cerasus humilis) seedlings. Plant Growth Regul. 74: 209218.

Zadranik T , Hollung K , Egge-Jacobsen W , Megli V , utar-Vozli J. 2013. Differential proteomic analysis of drought stress response in leaves of common bean (Phaseolus vulgaris L.). J. Proteom. 78: 254272.

Zapata PJ , Serrano M , Pretel MT , Amors A , Botella M . 2004. Polyamines and ethylene changes during germination of different plant species under salinity. Plant Sci. 167: 781788.

Zarza X , Atanasov KE , Marco F , Arbona V , Carrasco P , Kopka J , Fotopoulos V , Munnik T , Gmez-Cadenas A , Tiburcio AF , Alczar R. 2016. Polyamine oxidase 5 loss-of-function mutations in Arabidopsis thaliana trigger metabolic and transcriptional reprogramming and promote salt stress tolerance. Plant Cell Environ. 40: 527542. doi:10.1111/pce.12714.

Zhang G , Xu S , Hu Q , Mao W , Gong Y. 2014. Putrescine plays a positive role in salt-tolerance mechanisms by reducing oxidative damage in roots of vegetable soybean. J. Int. Agric. 13: 349357.

Zhao F , Song C-P , He J , Zhu H. 2007. Polyamines improve K+/Na+ homeostasis in barley seedlings by regulating root ion channel activities. Plant Physiol. 145: 10611072.

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Adam, S. A. , Nakagawa, T. , Swanson, M. S. , Woodruff, T. K. , and Dreyfuss, G. (1986). mRNA polyadenylate-binding protein: gene isolation and sequencing and identification of a ribonucleoprotein consensus sequence. Molecular and Cellular Biology, 6(8), 29322943.

Ambrosone, A. , Costa, A. , Leone, A. , and Grillo, S. (2012). Beyond transcription: RNA-binding proteins as emerging regulators of plant response to environmental constraints. Plant Science, 182, 1218.

Bocca, S. N. , Magioli, C. , Mangeon, A. , Junqueira, R. M. , Cardeal, V. , Margis, R. , and Sachetto-Martins, G. (2005). Survey of glycine-rich proteins (GRPs) in the Eucalyptus expressed sequence tag database (ForEST). Genetics and Molecular Biology, 28(3), 608624.

Brutus, A. , Sicilia, F. , Macone, A. , Cervone, F. , and De Lorenzo, G. (2010). A domain swap approach reveals a role of the plant wall-associated kinase 1 (WAK1) as a receptor of oligogalacturonides. Proceedings of the National Academy of Sciences, 107(20), 94529457.

Carpenter, C. D. , Kreps, J. A. , and Simon, A. E. (1994). Genes encoding glycine-rich Arabidopsis thaliana proteins with RNA-binding motifs are influenced by cold treatment and an endogenous circadian rhythm. Plant Physiology, 104(3), 10151025.

Condit, C. M. , McLean, B. G. , and Meagher, R. B. (1990). Characterization of the expression of the petunia glycine-rich protein-1 gene product. Plant Physiology, 93(2), 596602.

Condit, C. M. , and Meagher, R. B. (1986). A gene encoding a novel glycine-rich structural protein of petunia. Nature, 323, 178181.

Chen, A. P. , Zhong, N. Q. , Qu, Z. L. , Wang, F. , Liu, N. , and Xia, G. X. (2007). Root and vascular tissue-specific expression of glycine-rich protein AtGRP9 and its interaction with AtCAD5, a cinnamyl alcohol dehydrogenase, in Arabidopsis thaliana. Journal of Plant Research, 120(2), 337343.

de Oliveira, D. D. , Franco, L. O. , Simoens, C. , Seurinck, J. , Coppieters, J. , Botterman, J. , and Montagu, M. V. (1993). Inflorescence-specific genes from Arabidopsis thaliana encoding glycine-rich proteins. The Plant Journal, 3(4), 495507.

de Oliveira, D. E. , Seurinck, J. , Inz, D. , Van Montagu, M. , and Botterman, J. (1990). Differential expression of five Arabidopsis genes encoding glycine-rich proteins. The Plant Cell, 2(5), 427436.

Elo, A. , Lyznik, A. , Gonzalez, D. O. , Kachman, S. D. , and Mackenzie, S. A. (2003). Nuclear genes that encode mitochondrial proteins for DNA and RNA metabolism are clustered in the Arabidopsis genome. The Plant Cell, 15(7), 16191631.

Flores Fusaro, A. , and Sachetto-Martins, G. (2007). Blooming time for plant glycine-rich proteins. Plant Signaling and Behavior, 2(5), 386387.

Fusaro, A. , Mangeon, A. , Junqueira, R. M. , Rocha, C. A. B. , Coutinho, T. C. , Margis, R. , and Sachetto-Martins, G. (2001). Classification, expression pattern and comparative analysis of sugarcane expressed sequences tags (ESTs) encoding glycine-rich proteins (GRPs). Genetics and Molecular Biology, 24(14), 263273.

Fusaro, A. F. , Bocca, S. N. , Ramos, R. L. B. , Barrco, R. M. , Magioli, C. , Jorge, V. C. , Coutinho, T. C. , et al. (2007). AtGRP2, a cold-induced nucleo-cytoplasmic RNA-binding protein, has a role in flower and seed development. Planta, 225(6), 13391351.

Gmez, J. , Snchez-Martnez, D. , Stiefel, V. , Rigau, J. , Puigdomnech, P. , and Pags, M. (1988). A gene induced by the plant hormone abscisic acid in response to water stress encodes a glycine-rich protein. Nature, 334, 262264.

Graumann, P. , and Marahiel, M. A. (1996). Some like it cold: response of microorganisms to cold shock. Archives of Microbiology, 166(5), 293300.

Graumann, P. L. , and Marahiel, M. A. (1998). A superfamily of proteins that contain the cold-shock domain. Trends in Biochemical Sciences, 23(8), 286290.

Han, J. H. , Jung, Y. J. , Lee, H. J. , Jung, H. S. , Lee, K. O. , and Kang, H. (2013). The RNA chaperone and protein chaperone activity of Arabidopsis glycine-rich RNA-binding protein 4 and 7 is determined by the propensity for the formation of high molecular weight complexes. The Protein Journal, 32(6), 449455.

Hanano, S. , Sugita, M. , and Sugiura, M. (1996). Isolation of a novel RNA-binding protein and its association with a large ribonucleoprotein particle present in the nucleoplasm of tobacco cells. Plant Molecular Biology, 31(1), 5768.

Heintzen, C. , Nater, M. , Apel, K. , and Staiger, D. (1997). AtGRP7, a nuclear RNA-binding protein as a component of a circadian-regulated negative feedback loop in Arabidopsis thaliana. Proceedings of the National Academy of Sciences, 94(16), 85158520.

Hernndez-Lucero, E. , Rodrguez-Hernndez, A. A. , Ortega-Amaro, M. A. , and Jimnez-Bremont, J. F. (2014). Differential expression of genes for tolerance to salt stress in common bean (Phaseolus vulgaris L.). Plant Molecular Biology Reporter, 32(2), 318327.

Houston, N. L. , Fan, C. , Schulze, J. M. , Jung, R. , and Boston, R. S. (2005). Phylogenetic analyses identify 10 classes of the protein disulfide isomerase family in plants, including single-domain protein disulfide isomerase-related proteins. Plant Physiology, 137(2), 762778.

Hulo, N. , Bairoch, A. , Bulliard, V. , Cerutti, L. , Cuche, B. A. , de Castro, E. , Lachaize, C. , Langendijk-Genevaux, P. S. , and Sigrist, C. J. A. (2008). The 20 years of PROSITE. Nucleic Acids Research, 36(Database issue), D245D249.

Kar, B. , Nayak, S. , and Joshi, R. K. (2012). Classification and comparative analysis of Curcuma longa L. expressed sequences tags (ESTs) encoding glycine-rich proteins (GRPs). Bioinformation, 8(3), 142.

210 Karlson, D. , and Imai, R. (2003). Conservation of the cold shock domain protein family in plants. Plant Physiology, 131(1), 1215.

Karlson, D. , Nakaminami, K. , Toyomasu, T. , and Imai, R. (2002). A cold-regulated nucleic acid-binding protein of winter wheat shares a domain with bacterial cold shock proteins. Journal of Biological Chemistry, 277(38), 3524835256.

Keller, B. , Sauer, N. , and Lamb, C. J. (1988). Glycine-rich cell wall proteins in bean: gene structure and association of the protein with the vascular system. The EMBO Journal, 7(12), 3625.

Kim, J. S. , Jung, H. J. , Lee, H. J. , Kim, K. , Goh, C. H. , Woo, Y. , Oh, S. H. , Han, Y. S. , and Kang, H. (2008). Glycine-rich RNA-binding protein7 affects abiotic stress responses by regulating stomata opening and closing in Arabidopsis thaliana. The Plant Journal, 55(3), 455466.

Kim, J. Y. , Park, S. J. , Jang, B. , Jung, C. H. , Ahn, S. J. , Goh, C. H. , Cho, K. , Han, O. , and Kang, H. (2007a). Functional characterization of a glycine-rich RNA-binding protein 2 in Arabidopsis thaliana under abiotic stress conditions. The Plant Journal, 50(3), 439451.

Kim, J. S. , Park, S. J. , Kwak, K. J. , Kim, Y. O. , Kim, J. Y. , Song, J. , Jang, B. , Jung, C. H. , and Kang, H. (2007b). Cold shock domain proteins and glycine-rich RNA-binding proteins from Arabidopsis thaliana can promote the cold adaptation process in Escherichia coli. Nucleic Acids Research, 35(2), 506 506.

Kim, M. H. , Sasaki, K. , and Imai, R. (2009). Cold shock domain protein 3 regulates freezing tolerance in Arabidopsis thaliana. The Journal of Biological Chemistry, 284(35), 2345423460. doi:10.1074/jbc.M109.025791

Kim, M. H. , Sato, S. , Sasaki, K. , Saburi, W. , Matsui, H. , and Imai, R. (2013a). COLD SHOCK DOMAIN PROTEIN 3 is involved in salt and drought stress tolerance in Arabidopsis. FEBS Open Bio, 3, 438442. doi:10.1016/j.fob.2013.10.003

Kim, M. H. , Sonoda, Y. , Sasaki, K. , Kaminaka, H. , and Imai, R. (2013b). Interactome analysis reveals versatile functions of Arabidopsis COLD SHOCK DOMAIN PROTEIN 3 in RNA processing within the nucleus and cytoplasm. Cell Stress and Chaperones, 18(4), 517525. doi:10.1007/s12192-012-0398-3

Kim, Y. O. , Kim, J. S. , and Kang, H. (2005). Cold-inducible zinc finger-containing glycine-rich RNA-binding protein contributes to the enhancement of freezing tolerance in Arabidopsis thaliana. The Plant Journal, 42(6), 890900.

Kloks, C. P. , Spronk, C. A. , Lasonder, E. , Hoffmann, A. , Vuister, G. W. , Grzesiek, S. , and Hilbers, C. W. (2002). The solution structure and DNA-binding properties of the cold-shock domain of the human Y-box protein YB-1. Journal of Molecular Biology, 316(2), 317326.

Kster, T. , Meyer, K. , Weinholdt, C. , Smith, L. M. , Lummer, M. , Speth, C. , Grosse, I. , Weigel, D. , and Staiger, D. (2014). Regulation of pri-miRNA processing by the hnRNP-like protein AtGRP7 in Arabidopsis. Nucleic Acids Research, 42(15), 99259936; gku716.

Kwak, K. J. , Kim, H. S. , Jang, H. Y. , Kang, H. , and Ahn, S. J. (2016). Diverse roles of glycine-rich RNA-binding protein 7 in the response of camelina (Camelina sativa) to abiotic stress. Acta Physiologiae Plantarum, 38(5), 111.

Kwak, K. J. , Kim, Y. O. , and Kang, H. (2005). Characterization of transgenic Arabidopsis plants overexpressing GR-RBP4 under high salinity, dehydration, or cold stress. Journal of Experimental Botany, 56(421), 30073016.

Long, R. , Yang, Q. , Kang, J. , Zhang, T. , Wang, H. , Li, M. , and Zhang, Z. (2013). Overexpression of a novel salt stress-induced glycine-rich protein gene from alfalfa causes salt and ABA sensitivity in Arabidopsis. Plant Cell Reports, 32(8), 12891298.

Magioli, C. , Barrco, R. M. , Rocha, C. A. B. , de Santiago-Fernandes, L. D. , Mansur, E. , Engler, G. , Margis-Pinheiro, M. , and Sachetto-Martins, G. (2001). Somatic embryo formation in Arabidopsis and eggplant is associated with expression of a glycine-rich protein gene (Atgrp-5). Plant Science, 161(3), 559567.

Mangeon, A. , Junqueira, R. M. , and Sachetto-Martins, G. (2010). Functional diversity of the plant glycine-rich proteins superfamily. Plant Signaling and Behavior, 5(2), 99104.

Mangeon, A. , Magioli, C. , Menezes-Salgueiro, A. D. , Cardeal, V. , de Oliveira, C. , Galvo, V. C. , Margis, R. , Engler, G. , and Sachetto-Martins, G. (2009). AtGRP5, a vacuole-located glycine-rich protein involved in cell elongation. Planta, 230(2), 253265.

Mangeon, A. , Menezes-Salgueiro, A. D. , and Sachetto-Martins, G. (2017). Start me up: revision of evidences that AtGRP3 acts as a potential switch for AtWAK1. Plant Signaling and Behavior, 12(2), e1191733.

Mangeon, A. , Pardal, R. , Menezes-Salgueiro, A. D. , Duarte, G. L. , de Seixas, R. , Cruz, F. P. , Cardeal, V. , et al. (2016). AtGRP3 is implicated in root size and aluminum response pathways in Arabidopsis. PloS One, 11(3), e0150583.

Maris, C. , Dominguez, C. , and Allain, F. H. T. (2005). The RNA recognition motif, a plastic RNA-binding platform to regulate post-transcriptional gene expression. The FEBS Journal, 272(9), 21182131.

Mayfield, J. A. , Fiebig, A. , Johnstone, S. E. , and Preuss, D. (2001). Gene families from the Arabidopsis thaliana pollen coat proteome. Science, 292(5526), 24822485.

Mayfield, J. A. , and Preuss, D. (2000). Rapid initiation of Arabidopsis pollination requires the oleosin-domain protein GRP17. Nature Cell Biology, 2(2), 128130.

Nakaminami, K. , Karlson, D. T. , and Imai, R. (2006). Functional conservation of cold shock domains in bacteria and higher plants. Proceedings of the National Academy of Sciences, 103(26), 1012210127.

Nocker, S. , and Vierstra, R. D. (1993). Two cDNAs from Arabidopsis thaliana encode putative RNA binding proteins containing glycine-rich domains. Plant Molecular Biology, 21(4), 695699.

Ortega-Amaro, M. A. , Rodrguez-Hernndez, A. A. , Rodrguez-Kessler, M. , Hernndez-Lucero, E. , Rosales-Mendoza, S. , Ibez-Salazar, A. , Delgado-Snchez, P. , and Jimnez-Bremont, J. F. (2015). Overexpression of AtGRDP2, a novel glycine-rich domain protein, accelerates plant growth and improves stress tolerance. Frontiers in Plant Science, 5, 782.

Ortega-Amaro, M. A. , Rodrguez-Kessler, M. , Rodrguez-Hernndez, A. A. , Becerra-Flora, A. , Rosales-Mendoza, S. , and Jimnez-Bremont, J. F. (2016). Overexpression of ArGRDP2 gene in common bean hairy roots generates vigorous plants with enhanced salt tolerance. Acta Physiologiae Plantarum, 38, 66.

Park, A. R. , Cho, S. K. , Yun, U. J. , Jin, M. Y. , Lee, S. H. , Sachetto-Martins, G. , and Park, O. K. (2001). Interaction of the Arabidopsis receptor protein kinase Wak1 with a glycine-rich protein, AtGRP-3. Journal of Biological Chemistry, 276(28), 2668826693.

211 Park, J. H. , Suh, M. C. , Kim, T. H. , Kim, M. C. , and Cho, S. H. (2008). Expression of glycine-rich protein genes, AtGRP5 and AtGRP23, induced by the cutin monomer 16-hydroxypalmitic acid in Arabidopsis thaliana. Plant Physiology and Biochemistry, 46(11), 10151018.

Park, S. J. , Kwak, K. J. , Oh, T. R. , Kim, Y. O. , and Kang, H. (2009). Cold shock domain proteins affect seed germination and growth of Arabidopsis thaliana under abiotic stress conditions. Plant and Cell Physiology, 50, 869878.

Pendle, A. F. , Clark, G. P. , Boon, R. , Lewandowska, D. , Lam, Y. W. , Andersen, J. , Mann, M. , Lamond, A. I. , Brown, J. W. , and Shaw, P. J. (2005). Proteomic analysis of the Arabidopsis nucleolus suggests novel nucleolar functions. Molecular Biology of the Cell, 16(1), 260269.

Reddy, A. S. N. , and Poovaiah, B. W. (1987). Accumulation of a glycine rich protein in auxin-deprived strawberry fruits. Biochemical and Biophysical Research Communications, 147(3), 885891.

Ringli, C. , Hauf, G. , and Keller, B. (2001b). Hydrophobic interactions of the structural protein GRP1. 8 in the cell wall of protoxylem elements. Plant Physiology, 125(2), 673682.

Ringli, C. , Keller, B. , and Ryser, U. (2001a). Glycine-rich proteins as structural components of plant cell walls. Cellular and Molecular Life Sciences, 58(10), 14301441.

Rodrguez-Hernndez, A. A. , Muro-Medina, C. V. , Ramrez-Alonso, J. I. , and Jimnez-Bremont, J. F. (2017). Modification of AtGRDP1 gene expression affects silique and seed development in Arabidopsis thaliana. Biochemical and Biophysical Research Communications, 486(2), 252256.

Rodrguez-Hernndez, A. A. , Ortega-Amaro, M. A. , Delgado-Snchez, P. , Salinas, J. , and Jimnez-Bremont, J. F. (2014). AtGRDP1 Gene encoding a glycine-rich domain protein is involved in germination and responds to ABA signalling. Plant Molecular Biology Reporter, 32(6), 11871202.

Ryser, U. , and Ryser, B. (1992). Ultrastructural localization of a bean glycine-rich protein in unlignified primary walls of protoxylem cells. The Plant Cell, 4(7), 773783.

Ryser, U. , Schorderet, M. , Zhao, G. F. , Studer, D. , Ruel, K. , Haul, G. , and Keller, B. (1997). Structural cell-wall proteins in protoxylem development: evidence for a repair process mediated by a glycine-rich protein. The Plant Journal, 12(1), 97111.

Sachetto-Martins, G. , Fernandes, L. D. , Felix, D. B. , and de Oliveira, D. E. (1995). Preferential transcriptional activity of a glycine-rich protein gene from Arabidopsis thaliana in protoderm-derived cells. International Journal of Plant Sciences, 156(4), 460470.

Sachetto-Martins, G. , Franco, L. O. , and de Oliveira, D. E. (2000). Plant glycine-rich proteins: a family or just proteins with a common motif?. Biochimica et Biophysica Acta (BBA)-Gene Structure and Expression, 1492(1), 114.

Sasaki, K. , and Imai, R. (2011). Pleiotropic roles of cold shock domain proteins in plants. Frontiers in Plant Science, 2, 116. doi:10.3389/fpls.2011.00116

Sasaki, K. , Kim, M. H. , and Imai, R. (2007). Arabidopsis COLD SHOCK DOMAIN PROTEIN2 is a RNA chaperone that is regulated by cold and developmental signals. Biochemical and Biophysical Research Communications, 364(3), 633638.

Sasaki, K. , Kim, M. H. , and Imai, R. (2013). Arabidopsis COLD SHOCK DOMAIN PROTEIN 2 is a negative regulator of cold acclimation. New Phytologist, 198(1), 95102.

Sasaki, K. , Kim, M. H. , Kanno, Y. , Seo, M. , Kamiya, Y. , and Imai, R. (2015a). Arabidopsis COLD SHOCK DOMAIN PROTEIN 2 influences ABA accumulation in seed and negatively regulates germination. Biochemical and Biophysical Research Communications, 456(1), 380384.

Sasaki, K. , Liu, Y. , Kim, M. H. , and Imai, R. (2015b). An RNA chaperone, AtCSP2, negatively regulates salt stress tolerance. Plant Signaling and Behavior, 10(8), e1042637. doi:10.1080/15592324.2015.1042637

Schmidt, F. , Marnef, A. , Cheung, M. K. , Wilson, I. , Hancock, J. , Staiger, D. , and Ladomery, M. (2010). A proteomic analysis of oligo (dT)-bound mRNP containing oxidative stress-induced Arabidopsis thaliana RNA-binding proteins ATGRP7 and ATGRP8. Molecular Biology Reports, 37(2), 839845.

Schning, J. C. , Streitner, C. , Meyer, I. M. , Gao, Y. , and Staiger, D. (2008). Reciprocal regulation of glycine-rich RNA-binding proteins via an interlocked feedback loop coupling alternative splicing to nonsense-mediated decay in Arabidopsis. Nucleic Acids Research, 36(22), 69776987.

Singh, S. , Virdi, A. S. , Jaswal, R. , Chawla, M. , Kapoor, S. , Mohapatra, S. B. , Manoj, N. , Pareek, A. , Kumar, S. , and Singh, P. (2017). A temperature-responsive gene in sorghum encodes a glycine-rich protein that interacts with calmodulin. Biochimie, 137, 115123.

Sivaguru, M. , Ezaki, B. , He, Z. H. , Tong, H. , Osawa, H. , Baluka, F. , Volkmann, D. , and Matsumoto, H. (2003). Aluminum-induced gene expression and protein localization of a cell wall-associated receptor kinase in Arabidopsis. Plant Physiology, 132(4), 22562266.

Staiger, D. , Zecca, L. , Kirk, D. A. W. , Apel, K. , and Eckstein, L. (2003). The circadian clock regulated RNA-binding protein AtGRP7 autoregulates its expression by influencing alternative splicing of its own pre-mRNA. The Plant Journal, 33(2), 361371.

Steinert, P. M. , Mack, J. W. , Korge, B. P. , Gan, S. Q. , Haynes, S. R. , and Steven, A. C. (1991). Glycine loops in proteins: their occurence in certain intermediate filament chains, loricrins and single-stranded RNA binding proteins. International Journal of Biological Macromolecules, 13(3), 130139.

Streitner, C. , Danisman, S. , Wehrle, F. , Schning, J. C. , Alfano, J. R. , and Staiger, D. (2008). The small glycine-rich RNA binding protein AtGRP7 promotes floral transition in Arabidopsis thaliana. The Plant Journal, 56(2), 239250.

Streitner, C. , Kster, T. , Simpson, C. G. , Shaw, P. , Danisman, S. , Brown, J. W. , and Staiger, D. (2012). An hnRNP-like RNA-binding protein affects alternative splicing by in vivo interaction with transcripts in Arabidopsis thaliana. Nucleic Acids Research, 40(22), 1124011255.

Ueki, S. , and Citovsky, V. (2002). The systemic movement of a tobamovirus is inhibited by a cadmium-ion-induced glycine-rich protein. Nature Cell Biology, 4(7), 478486.

Urbez, C. , Cercs, M. , Perez-Amador, M. A. , and Carbonell, J. (2006). Expression of PsGRP1, a novel glycine rich protein gene of Pisum sativum, is induced in developing fruit and seed and by ABA in pistil and root. Planta, 223(6), 12921302.

Van Kan, J. A. , Cornelissen, B. J. , and Bol, J. F. (1988). A virus-inducible tobacco gene encoding a glycine-rich protein shares putative regulatory elements with the ribulose bisphosphate carboxylase small subunit gene. Molecular Plant-Microbe Interactions, 1(3), 107112.

212 Vermel, M. , Guermann, B. , Delage, L. , Grienenberger, J. M. , Marchal-Drouard, L. , and Gualberto, J. M. (2002). A family of RRM-type RNA-binding proteins specific to plant mitochondria. Proceedings of the National Academy of Sciences, 99(9), 58665871.

Yang, D. H. , Kwak, K. J. , Kim, M. K. , Park, S. J. , Yang, K. Y. , and Kang, H. (2014). Expression of Arabidopsis glycine-rich RNA-binding protein AtGRP2 or AtGRP7 improves grain yield of rice (Oryza sativa) under drought stress conditions. Plant Science, 214, 106112.

Yang, Y. , and Karlson, D. (2013). AtCSP1 regulates germination timing promoted by low temperature. FEBS Letters, 587(14), 21862192.

Yang, Y. , and Karlson, D. T. (2011). Overexpression of AtCSP4 affects late stages of embryo development in Arabidopsis. Journal of Experimental Botany, 62(6), 20792091. doi: 10.1093/jxb/erq400

Ziemienowicz, A. , Haasen, D. , Staiger, D. , and Merkle, T. (2003). Arabidopsis transportin1 is the nuclear import receptor for the circadian clock-regulated RNA-binding protein AtGRP7. Plant Molecular Biology, 53(12), 201212.

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Abebe T , Guenzi AC , Martin B , Cushman JC (2003) Tolerance of mannitol-accumulating transgenic wheat to water stress and salinity. Plant Physiol. 131:17481755.

Ahmad P , Sharma S (2008) Salt stress and phytobiochemical responses of plants. Plant Soil Environ. 54:8999.

Alcazar R , Marco F , Cuevas JC , Patron M , Ferrando A , Carrasco P , Tiburcio AF , Altabella T (2006) Involvement of polyamines in plant response to abiotic stress. Biotechnol. Lett. 28:18671876.

Al-Taweel K , Iwaki T , Yabuta Y , Shigeoka S , Murata N , Wadano A (2007) A bacterial transgene for catalase protects translation of d1 protein during exposure of salt-stressed tobacco leaves to strong light. Plant Physiol. 145:258265.

Ashraf M , Foolad MR (2007) Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environ. Exp. Bot. 59:206216.

Avonce N , Leyman B , Mascorro-Gallardo JO , Van Dijck P , Thevelein JM , Iturriaga G (2004) The Arabidopsis trehalose-6-P synthase AtTPS1 gene is a regulator of glucose, abscisic acid, and stress signaling. Plant Physiol. 136:36493659.

Barbosa JM , Singh NK , Cherry JH , Locy RD (2010) Nitrate uptake and utilization is modulated by exogenous-aminobutyric acid in Arabidopsis thaliana seedlings. Plant Physiol. Biochem. 48:443450.
Bohnert HJ , Shen BO (1998) Transformation and compatible solutes. Sci. Hortic. 78:237260.
Chen H , Jiang J-G (2010) Osmotic adjustment and plant adaptation to environmental changes related to drought and salinity. Environ. Rev. 18:309319.
Chen TH , Murata N (2002) Enhancement of tolerance of abiotic stress by metabolic engineering of betaines and other compatible solutes. Curr. Opin. Biotechnol. 5:250257.
Chen TH , Murata N (2008) Glycinebetaine: An effective protectant against abiotic stress in plants. Trends Plant Sci. 13:499505.
Chen THH , Murata N (2011) Glycine betaine protects plants against abiotic stress: Mechanisms and biotechnological applications. Plant Cell Environ. 34:120.
Chinnusamy V , Zhu JK (2009) Epigenetic regulation of stress responses in plants. Curr. Opin. Plant Biol. 12:133139.
Cortina C , Culianez-Macia FA (2005) Tomato abiotic stress enhanced tolerance by trehalose biosynthesis. Plant Sci. 169:7582.
Cramer GR , Urano K , Delrot S , Pezzotti M , Shinozaki K (2011) Effects of abiotic stress on plants: A systems biology perspective. BMC Plant Biol. 11:163.
Crowe JH (2007) Trehalose as a chemical chaperone: Fact and fantasy. Adv. Exp. Med. Biol. 594:143158.
dos Reis SP , Lima AM , de Souza CRB (2012) Recent molecular advances on downstream plant responses to abiotic stress. Int. J. Mol. Sci. 13:86288647.
El Sayed AI , Rafudeen MS , Golldack D (2014) Physiological aspects of raffi nose family oligosaccharides in plants: Protection against abiotic stress. Plant Biol. 16:18.
Elbein AD , Pan YT , Pastuszak I , Carroll D (2003) New insights on trehalose: A multifunctional molecule. Glycobiology 13:1727.
Fan W , Zhang M , Zhang H , Zhang P (2012) Improved tolerance to various abiotic stresses in transgenic sweet potato (Ipomoea batatas) expressing spinach betaine aldehyde dehydrogenase. PLoS One 7(5):e37344.
Fitzgerald TL , Waters DLE , Henry RJ (2009) Betaine aldehyde dehydrogenase in plants. Plant Biol. 11(2):119130.
Gosal SS , Wani SH , Kang MS (2009) Biotechnology and drought tolerance. J. Crop. Improv. 23:1954.
Groppa MD , Benavides MP (2008) Polyamines and abiotic stress: Recent advances. Amino Acids 34:3545.
He C , Yang A , Zhang W , Gao Q , Zhang J (2010) Improved salt tolerance of transgenic wheat by introducing betA gene for glycine betaine synthesis. Plant Cell Tiss. Organ Cult. 101:6578.
Hussain SS , Ali M , Ahmad M , Siddique KHM (2011) Polyamines: Natural and engineered abiotic and biotic stress tolerance in plants. Biotechnol. Adv. 29:300311.
Jagendorf AT , Takabe T (2001) Inducers of glycine betaine synthesis in barley. Plant Physiol. 127:18271835.
Juhsz Z , Balmer D , Ss-Hegeds A , Vallat A , Mauch-Mani B , Bnfalvi Z (2014) Effects of drought stress and storage on the metabolite and hormone contents of potato tubers expressing the yeast trehalose-6-phosphate synthase 1. Gene J. Agric. Sci. 6:142166.
Kanayama Y , Watanabe M , Moriguchi R , Deguchi M , Kanahama K , Yamaki S (2006) Effects of low temperature and abscisic acid on the expression of the sorbitol-6-phosphate dehydrogenase gene in apple leaves. J. Jpn. Soc. Hortic. Sci. 75:2025.
Karthikeyan A , Pandian SK , Ramesh M (2011) Transgenic indica rice cv. ADT 43 expressing a 1-pyrroline-5-carboxylate synthetase (P5CS) gene from Vigna aconitifolia demonstrates salt tolerance. Plant Cell Tiss. Organ Cult. 107:383395.
Khare T , Kumar V , Kavi Kishor PB (2015) Na+ and Cl ions show additive effects under NaCl stress on induction of oxidative stress and the responsive antioxidative defense in rice. Protoplasma. 252:11491165. doi:10.1007/s00709-014-0749-2.
219 Kinnersley AM , Turano FJ (2000) Gamma aminobutyric acid (GABA) and plant responses to stress. Crit. Rev. Plant Sci. 19:479509.
Koyro HW , Ahmad P , Geissler N (2012) Abiotic stress responses in plants: An overview. In: Ahmad P , Prasad MNV (eds.). Environmental Adaptations and Stress Tolerance of Plants in the Era of Climate Change. Springer, New York, pp. 128.
Krasensky J , Jonak C (2012) Drought, salt, and temperature stress-induced metabolic rearrangements and regulatory networks. J. Exp. Bot. 63:15931608.
Kumar S , Dhingra A , Daniell H (2004) Plastid-expressed betaine aldehyde dehydrogenase gene in carrot cultured cells, roots, and leaves confers enhanced salt tolerance. Plant Physiol. 136:28432854.
Kumar V , Khare T (2015) Individual and additive effects of Na+ and Cl ions on rice under salinity stress. Arch. Agron. Soil Sci. 61:381395.
Kumar V , Shriram V , Hoque TS , Hasan MM , Burritt DJ , Hossain MA (2016) Glycinebetaine mediated abiotic oxidative-stress tolerance in plants: Physiological and biochemical mechanisms. In: Sarwat M , Ahmad A , Abdin MZ , Ibrahim MM (eds.). Stress Signaling in Plants: Genomics and Proteomics Perspective, Vol. 2. Springer International Publishing, Switzerland.
Kumar V , Shriram V , Hossain MA , Kishor PK (2015) Engineering proline metabolism for enhanced plant salt stress tolerance. In: Wani SH , Hossain MA (eds.). Managing Salt Tolerance in Plants: Molecular and Genomic Perspectives. CRC Press, Boca Raton, pp. 353372.
Kumar V , Shriram V , Jawali N , Shitole MG (2007) Differential response of indica rice genotypes to NaCl stress in relation to physiological and biochemical parameters. Arch. Agron. Soil Sci. 53:581592.
Kumar V , Shriram V , Kavi Kishor PB , Jawali N , Shitole MG (2010). Enhanced proline accumulation and salt stress tolerance of transgenic indica rice by over-expressing P5CSF129A gene. Plant Biotechnol. Rep. 4:3748.
Kusano T , Yamaguchi K , Berberich T , Takahashi Y (2007) Advances in polyamine research in 2007. J. Plant Res. 120:345350.
Li F , Lei HJ , Zhao XJ , Tian RR , Li TH (2011) Characterization of three sorbitol transporter genes in micropropagated apple plants grown under drought stress. Plant Mol. Biol. Rep. 30:123130.
Liang X , Zhang L , Natarajan SK , Becker DF (2013) Proline mechanisms of stress survival. Antioxid. Redox Signal. 19:9981011.
Livingston DP , Hincha DK , Heyer AG (2009) Fructan and its relationship to abiotic stress tolerance in plants. Cell Mol. Life Sci. 66:20072023.
Lugan R , Niogret MF , Leport L , Gugan JP , Larher FR , Savour A , Kopka J , Bouchereau A (2010) Metabolome and water homeostasis analysis of Thellungiella salsuginea suggests that dehydration tolerance is a key response to osmotic stress in this halophyte. Plant J. 64:215229.
Lv WT , Lin B , Zhang M , Hua XJ (2011) Proline accumulation is inhibitory to Arabidopsis seedlings during heat stress. Plant Physiol. 15:19211933.
McCue KF , Hanson AD (1990) Drought and salt tolerance: Towards understanding and application. Trends Biotechnol. 8:358362.
Molinari HB , Marur CJ , Daros E , De Campos MK , De Carvalho JF , Pereira LF , Vieira LG (2007) Evaluation of the stressinducible production of proline in transgenic sugarcane (Saccharum spp.): Osmotic adjustment, chlorophyll fluorescence and oxidative stress. Physiol. Plant. 130:218229.
Munns R , Tester M (2008) Mechanism of salinity tolerance. Annu. Rev. Plant Biol. 59:651681.
Murakeozy EP , Nagy Z , Duhaze C , Bouchereau A , Tuba Z (2003) Seasonal changes in the levels of compatible osmolytes in three halophytic species of inland saline vegetation in Hungary. J. Plant Physiol. 160:395401.
Nahar K , Hasanuzzaman M , Fujita M (2016) Roles of osmolytes in plant adaptation to drought and salinity. In: Iqbal N , Nazar R , Khan NA (eds.). Osmolytes and Plants Acclimation to Changing Environment: Emerging Omics Technologies. Springer India, New Delhi, pp. 3768.

Pilon-Smits E , Ebskamp M , Paul MJ , Jeuken M , Weisbeek PJ , Smeekens S (1995) Improved performance of transgenic fructan-accumulating tobacco under drought stress. Plant Physiol. 107:125130.

Punji D , Chaudhary A , Rajam MV (2007). Increased tolerance to salinity and drought in transgenic indica rice by mannitol accumulation. J. Plant Biochem. Biotech. 16:17.

Ramakrishna A , Ravishankar GA (2011). Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal. Behav. 6:17201731.

Ramakrishna A , Ravishankar GA (2013). Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Tuteja N. . In: Gill SS (eds.). Climate Change and Plant Abiotic Stress Tolerance. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, pp. 705726.

Ranganayakulu GS , Veeranagamallaiah G , Sudhakar C (2013) Effect of salt stress on osmolyte accumulation in two groundnut cultivars (Arachis hypogaea L.) with contrasting salt tolerance. Afr. J. Plant Sci. 12:586592.

Renault H , Roussel V , Amrani E , Arzel M , Renault D , Bouchereau A , Deleu C (2010) The Arabidopsis pop2-1 mutant reveals the involvement of GABA transaminase in salt stress tolerance. BMC Plant Biol. 10:116.

Rhodes D , Hanson AD (1993) Quaternary ammonium and tertiary sulfonium compounds in higher-plants. Annu. Rev. Plant Physiol. Plant Mol. Biol. 44:357384.

Richards AB , Krakiwka S , Dexter LB , Schid H , Wolterbeek APM , Waalkens-Berendsen DH , Shigoyuki A , Kurimoto M (2002) Trehalose: A review of properties, history of use and human tolerance, and results of multiple studies. Food Chem. Toxicol. 40:871 871.

Roy M , Wu R (2002) Overexpression of S-adenosylmethionine decarboxylase gene in rice increases polyamine level and enhances sodium chloride-stress tolerance. Plant Sci. 163:987992.

Sah SK , Kaur G , Wani SH (2016) Metabolic engineering of compatible solute trehalose for abiotic stress tolerance in plants. In: Iqbal N , Nazar R , Khan NA (eds.). Osmolytes and Plants Acclimation to Changing Environment: Emerging Omics Technologies. Springer India, New Delhi, pp. 8396.

Sanghera GS , Wani SH , Hussain W , Singh NB (2011) Engineering cold stress tolerance in crop plants. Curr. Gen. 14:3043.

Sawahel W (2004) Improved performance of transgenic glycine betaine-accumulating rice plants under drought stress. Biol. Plant. 47:3944.

Shriram V , Kumar V , Devarumath RM , Khare T , Wani SH (2016) MicroRNAs as potent targets for abiotic stress tolerance in plants. Front. Plant Sci. 7:817. doi:10.3389/fpls.2016.00817.

220 Simon-Sarkadi L , Kocsy G , Vrhegyi , Galiba G , De Ronde JA (2006) Stress induced changes in the free amino acid composition in transgenic soybean plants having increased proline content. Biol. Plant. 50:793796.

Slama I , Abdelly C , Bouchereau A , Flowers T , Savour A (2015) Diversity, distribution and roles of osmoprotective compounds accumulated in halophytes under abiotic stress. Ann. Bot. 115:433447.

Suprasanna P , Nikalje GC , Rai AN (2016) Osmolyte accumulation and implication in plant abiotic stress tolerance. In: Iqbal N , Nazar R , Khan NA (eds.). Osmolytes and Plants Acclimation to Changing Environment: Emerging Omics Technologies, Springer India, New Delhi, pp. 112.

Szabados L , Savoure A (2010) Proline: A multifunctional amino acid. Trends Plant Sci. 15:8997.

Takahashi S , Murata N (2008) How do environmental stresses accelerate photoinhibition? Trends Plant Sci. 13:178182.

Tan JL , Wang CY , Xiang B , Han R , Guo Z (2013) Hydrogen peroxide and nitric oxide mediated cold- and dehydration induced myo-inositol phosphate synthase that confers multiple resistances to abiotic stresses. Plant Cell Environ. 36:288299.

Tari I , Kiss G , Deer AK , Csiszr J , Erdei L , Gall , Gemes K , et al. (2010) Salicylic acid increased aldose reductase activity and sorbitol accumulation in tomato plants under salt stress. Biol. Plant. 54:677683.

Van den Ende W , Valluru R (2009) Sucrose, sucrosyl oligosaccharides, and oxidative stress: Scavenging and salvaging? J. Exp. Bot. 60:918.

Vendruscolo ECG , Schuster I , Pileggi M , Scapim CA , Molinari HBC , Marur CJ , Vieira LG (2007) Stress-induced synthesis of proline confers tolerance to water deficit in transgenic wheat. J. Plant Physiol. 164:13671376.

Vinocur B , Altman A (2005) Recent advances in engineering plant tolerance to abiotic stress: Achievements and limitations. Curr. Opin. Biotechnol. 16:123132.

Wang GP , L i F , Zhang J , Zhao MR , Hui Z , Wang W (2010) Overaccumulation of glycine betaine enhances tolerance of the photosynthetic apparatus to drought and heat stress in wheat. Photosynthetica. 48:3041.

Wang Z , Zhang S , Yang B , Li Y (2005) Trehalose synthase gene transfer mediated by Agrobacterium tumefaciens enhances resistance to osmotic stress in sugarcane. Sugar Tech. 7:4954.

Wani SH , Singh NB , Haribhushan A , Mir JI (2013) Compatible solute engineering in plants for abiotic stress toleranceRole of glycine betaine. Curr. Gen. 14(3):157165.

Pathak MR , Wani SH (2015) Salinity stress tolerance in relation to polyamine metabolism in plants. In: Wani SH , Hossain MA (eds.) Managing Salt Tolerance in Plants: Molecular and Genomic Perspectives. CRC Press, Boca Raton, pp. 241250.

Wani SH , Gosal SS (2010) Genetic engineering for osmotic stress tolerance in plants-role of proline. IUP J. Genet. Evol. 3(4):1425.

Wani SH , Gosal SS (2011) Introduction of OsglyII gene into Indica rice through particle bombardment for increased salinity tolerance. Biol. Plant. 55(3):536540.

Wani SH , Kumar V , Shriram V , Sah S.K. (2016a) Phytohormones and their metabolic engineering for abiotic stress tolerance in crop plants. Crop J. 4(3):162176. doi:10.1016/j.cj.2016.01.010.

Wani SH , Sah SK , Hussain MA , Kumar V , Balachandra SM (2016b) Transgenic approaches for abiotic stress tolerance in crop plants. In: Al-Khayri JM , Jain SM , Johnson DV (eds.). Advances in Plant Breeding Strategies, Vol. 2: Agronomic, Abiotic and Biotic Stress Traits. Springer International Publishing, Switzerland.

Witt S , Galicia L , Lisec J , Cairns J , Tiessen A , Araus JL , Palacios-Rojas N , Fernie AR (2012) Metabolic and phenotypic responses of greenhouse-grown maize hybrids to experimentally controlled drought stress. Mol. Plant. 5:401417.

Yamada M , Morishita H , Urano K , Shiozaki N , Yamaguchi-Shinozaki K , Shinozaki K , Yoshiba Y (2005) Effects of free proline accumulation in petunias under drought stress. J. Exp. Bot. 56:19751981.

Yang X , Liang Z , Wen X , Lu C (2008) Genetic engineering of the biosynthesis of glycinebetaine leads to increased tolerance of photosynthesis to salt stress in transgenic tobacco plants. Plant Mol. Biol. 66:7386.

Zhang H , Dong H , Li W , Sun Y , Chen S , Kong X (2009) Increased glycine betaine synthesis and salinity tolerance in AhCMO transgenic cotton lines. Mol. Breed. 23(2):289298.

Zhang J , Zhang Y , Du Y , Chen S , Tang H (2011) Dynamic metabolomics responses of Tobacco (Nicotiana tabacum) plants to salt stress. J. Proteome Res. 10:19041914.

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Afreen F , Zobayed S , Kozai T (2006) Melatonin in Glycyrrhiza uralensis: Response of plant roots to spectral quality of light and UV-B radiation. J. Pineal Res. 41:108115.

225 Andaya V , Mackill D (2003) QTLs conferring cold tolerance at the booting stage of rice using recombinant inbred lines from a japonica indica cross. Theor. Appl. Genet. 106:10841090.

Arnao MB , Hernandez-Ruiz A (2009) Protective effect of melatonin against chlorophyll degradation during the senescence of barley leaves. J. Pineal Res. 46:5863.

Arora D , Bhatla SC (2017) Melatonin and nitric oxide regulate sunflower seedling growth under salt stress accompanying differential expression of Cu/Zn SOD and Mn SOD. Free Rad. Biol. Med. 106: 315.

Bajwa VS , Shukla MR , Sherif SM , Murch SJ , Saxena PK (2014) Role of melatonin in alleviating cold stress in Arabidopsis thaliana. J. Pineal Res. 56:238245.

Bennett RN , Wallsgrove RM (1994) Secondary metabolites in plant defense mechanisms. New Phytol. 127:617633.

Byeon Y , Back KW (2013) Melatonin synthesis in rice seedlings in vivo is enhanced at high temperatures and under dark conditions due to increased serotonin N-acetyltransferase and N-acetylserotonin methyltransferase activities. J. Pineal Res. 56:189195.

Byeon Y , Lee HY , Hwang OJ , Lee HJ , Lee K , Back K (2015). Coordinated regulation of melatonin synthesis and degradation genes in rice leaves in response to cadmium treatment. J Pineal Res. 58:470478. doi:10.1111/jpi.12232.

Cai S-Y , Zhang Y , Xu Y-P , Qi ZY , Li MQ , Ahammed GJ , et al. (2017) HsfA1a up regulates melatonin biosynthesis to confer cadmium tolerance in tomato plants. J. Pineal Res. 62:e12387.

Cui G , Zhao X , Liu S , Sun F , Zhang C , Xi Y (2017) Beneficial effects of melatonin in overcoming drought stress in wheat seedlings. Plant Physiol. Biochem. 118: 138e149.

Dubbels R , Reiter RJ , Klenke E , Goebel A , Schnakenberg E , Ehlers C , et al. (1995) Melatonin in edible plants identified by radioimmunoassay and by high performance liquid chromatographymass spectrometry. J. Pineal Res. 18:2831.

Erland LAE , Murch SJ , Reiter RJ , Saxena PK (2015) A new balancing act: The many roles of melatonin and serotonin in plant growth and development. Plant Signal. Behav. 10:e1096469e1096415.

Flora SJS , Shrivastava R , Mittal M (2013) Chemistry and pharmacological properties of some natural and synthetic antioxidants for heavy metal toxicity. Curr. Med. Chem. 20:45404574.

Fu J , Wu Y , Miao Y , Xu Y , Zhao E , Wang J , et al. (2017) Improved cold tolerance in Elymus nutans by exogenous application of melatonin may involve ABA-dependent and ABA-independent pathways. Sci. Rep. 7:39865. doi:10.1038/srep39865.

Gill SS , Tuteja N (2010) Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol. Biochem. 48:909930.

Han QH , Huang B , Ding CB , Zhang ZW , Chen YE , Hu C , et al. (2017) Effects of melatonin on anti-oxidative systems and Photosystem II in cold-stressed rice seedlings. Front. Plant Sci. 8: 785.

Hardeland R , Pandi-Perumal SR , Poeggeler B (2007) Melatonin in plantsFocus on a vertebrate night hormone with cytoprotective properties. Funct. Plant Sci. Biotech. 1:3245.

Hu ZR , Fan JB , Xie Y , Amombo E , Liu A , Gitau MM , et al. (2016) Comparative photosynthetic and metabolic analyses reveal mechanism of improved cold stress tolerance in bermudagrass by exogenous melatonin. Plant Physiol. Biochem. 100:94104. doi:10.1016/j.plaphy.2016. 01.008.

Hulya T , Serkan E , Mucip G , Okkes A , Yavuz D , Derya Y (2014) The regulatory effect of melatonin on physiological, biochemical and molecular parameters in cold-stressed wheat seedlings. Plant Growth Regul. 74:139152.

Jiang C , Cui Q , Feng K , Xu D , Li C , Zheng Q (2016) Melatonin improves antioxidant capacity and ion homeostasis and enhances salt tolerance in maize seedlings. Acta Physiol. Plant. 38:19.

Kang K , Lee K , Park S , Kim YS , Back K (2010) Enhanced production of melatonin by ectopic overexpression of human serotonin N-acetyltransferase plays a role in cold resistance in transgenic rice seedlings. J. Pineal Res. 49:176182.

Kang S , Kang K , Lee K , Back K (2007) Characterization of tryptamine 5-hydroxylase and serotonin synthesis in rice plants. Plant Cell Rep. 26:20092015.

Kaur H , Mukherjee S , Baluska F , Bhatla SC (2015) Regulatory roles of serotonin and melatonin in abiotic stress tolerance in plants. Plant Signal. Behav. 10:e1049788. doi:10.1080/15592324.2015.1049788.

Kolar J , Machackova I , Eder J , Prinsen E , van Dongen W , van Onckelen H , Illnerova H (1997) Melatonin: Occurrence and daily rhythm in Chenopodium rubrum. Phytochemistry 8:14071413.

Lei X-Y , Zhu R-Y , Zhang G-Y , Dai Y-R (2004) Attenuation of cold-induced apoptosis by exogenous melatonin in carrot suspension cells: The possible involvement of polyamines. J. Pineal Res. 36:126131.

Li H , Chang J , Chen H , Wang Z , Gu X , Wei C , et al. (2017) Exogenous melatonin confers salt stress tolerance to watermelon by improving photosynthesis and redox homeostasis. Front. Plant Sci. 8:295.

Li H , Chang J , Zheng J , Dong Y , Liu Q , Yang X , et al. (2017) Local melatonin application induces cold tolerance in distant organs of Citrullus lanatus L. via long distance transport. Sci. Rep. 7:40858.

Li C , Wang P , Wei Z , Liang D , Liu C , Yin L , et al. (2012) The mitigation effects of exogenous melatonin on salinity-induced stress in Malus hupehensis. J. Pineal Res. 53:298306.

Li C , Tan DX , Liang D , Chang C , Jia D , Ma F (2015) Melatonin mediates the regulation of ABA metabolism, free-radical scavenging and stomatal behavior in two Malus species under drought stress. J. Exp. Bot. 66:669680.

Li X , Tan DX , Jiang D , Liu F (2016) Melatonin enhances cold tolerance in drought-primed wild-type and abscisic acid-deficient mutant barley. J. Pineal Res. 61:328339.

Liang C , Zheng G , Li W , Wang Y , Hu B , Wang H , et al. (2015) Melatonin delays leaf senescence and enhances salt stress tolerance in rice. J. Pineal Res. 59:91101. doi:10.1111/jpi.12243.

Limson J , Nyokong T , Daya S (1998) The interaction of melatonin and its precursors with aluminum, cadmium, copper, iron, lead and zinc: An adsorptive voltammetric study. J. Pineal Res. 24:1521.

Lin Q , Zhang JS , Chen SY (2015) Melatonin enhances plant growth and maize (Zea mays L.) seedling drought tolerance by alleviating drought-induced photosynthetic inhibition and oxidative damage. Acta Physiol. Plant 38:48.

Liu J , Wang W , Wang L , Sun Y (2015) Exogenous melatonin improves seedling health index and drought tolerance in tomato. J. Plant Growth Regul. 77:317326.

Mukherjee S , David A , Yadav S , Baluka F , Bhatla SC (2014) Salt stress-induced seedling growth inhibition coincides with differential distribution of serotonin and melatonin in sunflower seedling roots and cotyledons. Physiol. Plant 152:714728.

226 Murch SJ , Alan AR , Cao J , Saxena, PK (2009) Melatonin and serotonin in flowers and fruits of Datura metel L. J. Pineal Res. 47:277283.

Murch SJ , Campbell SSB , Saxena PK (2001) The role of serotonin and melatonin in plant morphogenesis: Regulation of auxin induced root organogenesis in in vitro-cultured explants of St. Johns wort (Hypericum perforatum L.). In Vitro Cell Dev. Biol. Plant 37:786793.

Murch SJ , Saxena PK (2002) Melatonin: A potential regulator of plant growth and development? In Vitro Cell Dev. Biol. Plant 38:531536.

Odjakova M , Hadjiivanova C (1997) Animal neurotransmitter substances in plants. Bulg. J. Plant Physiol. 23:94102.

Paredes SD , Korkmaz A , Manchester LC , Tan DX , Reiter RJ (2009) Phytomelatonin: A review. J. Exp. Bot. 60:5769.

Parmar P , Limson J , Nyokong T , Daya S (2002) Melatonin protects against copper-mediated free radical damage. J. Pineal Res. 32:237242.

Posmyk MM , Kuran H , Marciniak K , Janas KM (2008) Presowing seed treatment with melatonin protects red cabbage seedlings against toxic copper ion concentrations. J. Pineal Res. 45:2431.

Posmyk MM , Baabusta M , Wieczorek M , Sliwinska E , Janas KM (2009) Melatonin applied to cucumber (Cucumis sativus L.) seeds improves germination during chilling stress. J. Pineal Res. 46:214223.

Ramakrishna A (2015) Indoleamines in edible plants: Role in human health effects. In: Indoleamines: Sources, Role in Biological Processes and Health Effects, Angel Catal (ed.). Biochemistry Research Trends Series. Nova Publishers. Biochemistry Research Trends, p. 279. ISBN: 978-1-63482-097-4.

Ramakrishna A , Dayananda C , Giridhar P , Rajasekaran T , Ravishankar GA (2011a). Photoperiod influence endogenous indoleamines in cultured green alga Dunaliella bardawil. Indian J. Exp. Biol. 49:234240.

Ramakrishna A , Giridhar P , Ravishankar GA (2011b) Phytoserotonin: A review. Plant Signal. Behav. 6:800809.

Ramakrishna A , Giridhar P , Ravishankar GA (2009) Indoleamines and calcium channels influence morphogenesis i n in vitro cultures of Mimosa pudica L. Plant Signal. Behav. 12:11361141.

Ramakrishna A , Giridhar P , Udaya Sankar K , Ravishankar GA (2012a) Endogenous profiles of indoleamines: Serotonin and melatonin in different tissues of Coffea canephora P ex Fr. as analyzed by HPLC and LC-MS-ESI. Acta Physiol. Plant 34:393396.

Ramakrishna A , Giridhar P , Udaya Sankar K , Ravishankar GA (2012b) Melatonin and serotonin profiles in beans of Coffea sps. J. Pineal Res. 52:470476.

Ramakrishna A , Giridhar P , Jobin M , Paulose CS , Ravishankar GA (2012c) Indoleamines and calcium enhance somatic embryogenesis in cultured tissues of Coffea canephora P ex Fr. Plant Cell Tissue Organ Cult. 108:267278.

Ramakrishna A , Ravishankar GA (2011) Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal Behav. 6:17201731.

Ramakrishna A , Ravishankar GA (2013) Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Climate Change and Abiotic Stress Tolerance, Tuteja N , Gill SS (eds). Wiley-VCH, Weinheim. ISBN 978-3-527-33491-9.

Ravishankar GA , Ramakrishna A (2016) Serotonin and Melatonin: Their Functional Role in Plants, Food, Phytomedicine, and Human Health. Taylor & Francis, CRC Press, Boca Raton, p. 568. ISBN 9781498739054.

Roshchina VV (2001) Neurotransmitters in Plant Life. Science Publishers, Enfield, pp. 481. ISBN 9781578081424.

Sanchez-Barcelo EJ , Mediavilla MD , Vriend J , Reiter RJ (2016) Constitutive photo morphogenesis protein 1 (COP1) and COP9 signal some, evolutionarily conserved photomorphogenic proteins as possible targets of melatonin. J. Pineal Res. 61:4151. doi:10.1111/jpi.12340.

Shi H , Chan Z (2014) The cysteine2/histidine2-type transcription factor Zinc Finger of Arabidopsis thaliana 6-activated C-repeat-Binding factor pathway is essential form melatonin-mediated freezing stress resistance in Arabidopsis. J. Pineal Res. 57:185191.

Shi H , Tan D-X , Reiter RJ , Ye T , Yang F , Chan Z (2015a) Melatonin induces class A1 heat-shock factors (HSFA1s) and their possible involvement of thermo tolerance in Arabidopsis. J Pineal Res. 58:335342.

Shi H , Jiang C , Ye T , Tan DX , Reiter RJ , Zhang H , et al. (2015b). Comparative physiological, metabolomic, and transcriptomic analyses reveal mechanisms of improved abiotic stress resistance in bermudagrass [Cynodon dactylon (L). Pers.] by exogenous melatonin. J. Exp. Bot. 66:681694. doi:10.1093/jxb/eru373.

Shi H , Qian Y , Tan DX , Reiter RJ , He C (2015c) Melatonin induces the transcripts of CBF/DREBs and their involvement in abiotic and biotic stresses in Arabidopsis. J. Pineal Res. 59:334342. doi:10.1111/jpi.12262.

Shi H , Reiter RJ , Tan DX , Chan Z (2015d) INDOLE-3-ACETIC ACID INDUCIBLE 17 positively modulates natural leaf senescence through melatonin-mediated pathway in Arabidopsis. J. Pineal Res. 58:2633. doi:10.1111/jpi.12188.

Shi H , Tan DX , Reiter RJ , Ye T , Yang F , Chan Z (2015f) Melatonin induces class A1heat-shock factors (HSFA1s) and their possible involvement of thermo tolerance in Arabidopsis. J. Pineal Res. 58:335342.

Shi H , Wang X , Tan DX , Reiter RJ , Chan Z (2015f) Comparative physiological and proteomic analyses reveal the actions of melatonin in the reduction of oxidative stress in Bermuda grass (Cynodon dactylon (L). Pers.). J. Pineal Res. 59:120131. doi:10.1111/jpi.12246.

Szafraska K , Szewczyk R , Janas K (2014) Involvement of melatonin applied to Vigna radiata L. seeds in plant response to chilling stress. Cent. Eur. J. Biol. 9:11171126.

Tan DX , Manchester LC , Helton P , Reiter RJ (2007) Phytoremediative capacity of plants enriched with melatonin. Plant Signal. Behav. 2:514516.

Tiryaki I , Keles H (2012) Reversal of the inhibitory effect of light and high temperature on germination of Phacelia tanacetifolia seeds by melatonin. J. Pineal Res. 52:332339.

Uchendu EE , Shukla MR , Reed BM , Saxena PK (2013) Melatonin enhances the recovery of cryopreserved shoot tips of American elm (Ulmus americana L.). J. Pineal Res. 55:435442.

Wang P , Sun X , Wang N , Tan DX , Ma F (2015) Melatonin enhances the occurrence of autophagy induced by oxidative stress in Arabidopsis seedlings. J. Pineal Res. 58:479489. doi:10.1111/jpi.12233.

Wang P , Sun X , Xie Y , Li M , Chen W , Zhang S , et al. (2014) Melatonin regulates proteomic changes during leaf senescence in Malushupehensis. J. Pineal Res. 57:291307. doi:10.1111/jpi.12169.

227 Wang P , Yin L , Liang D , Li C , Ma F , Yue Z (2012) Delayed senescence of apple leaves by exogenous melatonin treatment: Toward regulating the ascorbate-glutathionecycle. J. Pineal Res. 53:1120. doi:10.1111/j.1600-079X.2011.00966.x

Weeda S , Zhang N , Zhao X , Ndip G , Guo Y , Buck GA , et al. (2014) Arabidopsis transcriptome analysis reveals key roles of melatonin in plant defense systems. PLoS One 9:e93462. doi:10.1371/journal.pone.0093462.

Xu W , Cai S-Y , Zhang Y , Wang Y , Ahammed GJ , Xia X-J , et al. (2016) Melatonin enhances thermotolerance by promoting cellular protein protection in tomato plants. J. Pineal Res. 61:457469.

Zhang HX , Blumwald E (2001) Transgenic salt-tolerant tomato plants accumulate salt in foliage but not in fruit. Nat. Biotech. 19:765768.

Zhang N , Sun Q , Zhang H , Cao Y , Weeda S , Ren S , et al. (2015) Roles of melatonin in abiotic stress resistance in plants. J. Exp. Bot. 66:647656.

Zhang YP , Yang SJ , Chen YY (2017) Effects of melatonin on photosynthetic performance and antioxidants in melon during cold and recovery. Biol. Plant 61:571578.

Zhang HJ , Zhang N , Yang RC , Wang L , Sun QQ , Li DB , et al. (2014) Melatonin promotes seed germination under high salinity by regulating antioxidant systems, ABA and GA interaction in cucumber (Cucumis sativus L.). J. Pineal Res. 57:269279.

Zhang N , Zhao B , Zhang HJ , Weeda S , Yang C , Yang ZC , et al. (2013) Melatonin promotes water-stress tolerance lateral root formation and seed germination in cucumber (Cucumis sativus L.). J. Pineal Res. 54:1523.

Zhao Y , Qi LW , Wang WM , Saxena PK , Liu CZ (2011) Melatonin improves the survival of cryopreserved callus of Rhodiola crenulata. J. Pineal Res. 50:8388.

Zheng XD , Zhou JZ , Tan DX , Wang N , Wang L , Shan DQ , et al. (2017) Melatonin improves waterlogging tolerance of Malus baccata (Linn.) Borkh. Seedlings by maintaining aerobic respiration, photosynthesis and ROS migration. Front. Plant Sci. 8:483. doi:10.3389/fpls.2017.00483.

Zolla G , Heimer YM , Barak S (2010) Mild salinity stimulates a stress-induced morphogenic response in Arabidopsis thaliana roots. J. Exp. Bot. 61:211224.

Zuo B , Zheng X , He P , Wang L , Lei Q , Feng C , et al. (2014) Overexpression of MzASMT improves melatonin production and enhances drought tolerance in transgenic Arabidopsis thaliana plants. J. Pineal Res. 57:408417.

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Aharoni A , De Vos CHR , Wein M , Sun Z , Greco R , Kroon A , Mol JN , OConnell A.P. The strawberry FaMYB1 transcription factor suppresses anthocyanin and flavonol accumulation in transgenic tobacco. Plant J. 2001;28:319332.

Aron PM , Kennedy J.A. Flavan-3-ols: Nature, occurrence and bi ological activity. Mol. Nutr. Food Res. 2008;52:79104.

Bahler BD , Steffen KL , Orzolek M.D. Morphological and biochemical comparison of a purple-leafed and a green-leafed pepper cultivar. HortScience 1991;26:736.

Bai S , Kasai A , Yamada K , Li T , Harada T. A mobile signal transported over a long distance induces systemic transcriptional gene silencing in a grafted partner. J. Exp. Bot. 2011;62:45614570.

Barz W , Welle R. Biosynthesis and metabolism of isoflavones and pterocarpan phytoalexins in chickpea, soybean and phytopathogenic fungi. In: Stafford H , Ibrahim R. (eds.) Phenolic Metabolism in Plants. Plenum Press, New York, pp. 139164 Chemistry 2012;53:33133320.

Bros W , Heller W , Michel C , Saran M. Flavonoids as antioxidant, determination of radical-scavenging efficiency. Methods Enzymol. 1990;186:343355.

Burger J , Edwards G.E. Photosynthetic efficiency, and photo damage by UV and visible radiation, in red versus green leaf of coleus varieties. Plant Cell Physiol. 1996;37:395399.

Chalker-Scott L. Do anthocyanins function as osmoregulators in leaf tissues? Adv. Bot. Res. 2002;37:104129.

Chalker-Scott L. Environmental significance of anthocyanins in plant stress responses. J. Photochem. Photobiol. 1999;70:19.

Chemler JA , Koffas M.A.G. Metabolic engineering for plant natural product biosynthesis in microbes. Curr. Opin. Biotechnol. 2008;19:597605.

Chemler JA , Lock LT , Koffas MAG , Tzanakakis E.S. Standardized biosynthesis of flavan-3-ols with effects on pancreatic beta-cell insulin secretion. Appl. Microbiol. Biotechnol. 2007;77:797807.

Czemmel S , Heppel SC , Bogs J. R2R3 MYB transcription factors: Key regulators of the flavonoid biosynthetic pathway in grapevine. Protoplasma 2012;249:S109S118.

Dixon RA , Sumner L.W. Role of anthocyanidin reductase, encoded by BANYULS in plant flavonoid biosynthesis. Plant Physiol. 2003;131:878885.

Dixon RA , Xie DY , Sharma S.B. Proanthocyanidinsa final frontier in flavonoid research? New Phytol. 2005;165:928.

Feyissa DM , Lvdal T , Olsen KM , Slimestad R , Lillo C. The endogenous GL3, but not EGL3, gene is necessary for anthocyanin synthesis as induced by nitrogen depletion in Arabidopsis rosette stage leaves. Planta 2009;230:747754.

Gidda SK , Varin L. Biochemical and molecular characterization of flavonoid 7-sulfotransferase from Arabidopsis thaliana. Plant Physiol. Biochem. 2006;44:628636.

Gonzalez A , Zhao M , Leavitt JM , Lloyd A.M. Regulation of the anthocyanin biosynthetic pathway by the TTG1/bHLH/Myb transcriptional complex in Arabidopsis seedlings. Plant J. 2008;53:814827.

Gould K.S. Natures Swiss army knife: The diverse protective roles of anthocyanins in leaves. J. Biomed. Biotechnol. 2004;2004:314320.

Gould KS , Lister C. Flavonoid functions in plants. In: Andersen M , Markham KR (eds.). Flavonoids. Chemistry, Biochemistry, and Applications. CRC Press, Boca Raton, 2006, pp. 397441.

Griesser M , Hoffmann T , Bellido ML , Rosati C , Fink B , Kurtzer R , Aharoni A , Munoz-Blanco J , Schwab W. Redirection of flavonoid biosynthesis through the down-regulation of an anthocyanidin glucosyltransferase in ripening strawberry fruit. Plant Physiol. 2008;146:15281539.

Grotewold E , Chamberlin M , Snook M , Siame B , Butler L , Swenson J , Maddock S , St Clair G , Bowen B. Engineering secondary metabolism in maize cells by ectopic expression of transcription factors. Plant Cell 1998;10:721740.

Grotewold E , Sainz MB , Tagliani L , Hernandez JM , Bowen B , Chandler V.L. Identification of the residues in the Myb domain of maize C1 that specify the interaction with the bHLH cofactor R. Proc. Natl. Acad. Sci. USA 2000;97:1357913584.

Guo J , Han W , Wang M.H. Ultraviolet and environmental stresses involved in the induction and regulation of anthocyanin biosynthesis: A review. Afr. J. Biotechnol. 2008;7:49664972.

Hada M , Hashimoto T , Nikaido O , Shin M. UVB-induced DNA damage and its photorepair in nuclei and chloroplasts of Spinacia oleracea L. J. Photochem. Photobiol. 1998;68:319322.

Han Y , Vimolmangkang S , Soria-Guerra RE , Korban S.S. Introduction of apple ANR genes into tobacco inhibits expression of both CHI and DFR genes in flowers, leading to loss of anthocyanin. J. Exp. Bot. 2012a;63:24372447.

236 Han Y , Vimolmangkang S , Soria-Guerra RE , Rosales-Mendoza S , Zheng D , Lygin AV , Korban S.S. Ectopic expression of apple F3H genes contributes to anthocyanin accumulation in the Arabidopsis tt7 mutant grown under nitrogen stress. Plant Physiol. 2012b;153:806820.

Hancock KR , Collette V , Fraser K , Greig M , Hong X , Richardson K , Jones C , Rasmussen S . Expression of the R2R3-MYB transcription factor TaMYB14 from Trifolium arvense activates proanthocyanidin biosynthesis in the legumes Trifolium repens and Medicago sativa. Plant Physiol. 2012;159:12041220.

Harborne JB , Grayer R.J. Flavonoids and insects. In: Harborne JB (ed.). The Flavonoids: Advances in Research since 1986. Chapman and Hall, London, 1993, pp. 589618.

Henry-Kirk RA , McGhie TK , Andre CH , Hellens RP , Allan A.C. Transcriptional analysis of apple fruit proanthocyanidin biosynthesis. J. Exp. Bot. 2012;63:54375450.

Hernndez I , Alegre L , Munn-Bosch S . Drought-induced changes in flavonoids and other low molecular weight antioxidants in Cistus clusii under Mediterranean filed conditions. Tree Physiol. 2004;24:13031311.
Hichri I , Barrieu F , Bogs J , Kappel C , Delrot S , Lauvergeat V. Recent advances in the transcriptional regulation of the flavonoid biosynthetic pathway. J. Exp. Bot. 2011;62:24652483.
Hoffmann T , Kalinowski G , Schwab W. RNAi-induced silencing of gene expression in strawberry fruit (Fragaria x ananassa) by agrofiltration: A rapid assay for gene function analysis. Plant J. 2006;48:818826.
Huang J , Gu M , Lai Z , Fan B , Shi K , Zhou YH , Yu JQ , Chen Z. Functional analysis of the Arabidopsis PAL gene family in plant growth, development, and response to environmental stress. Plant Physiol. 2010;153:15261538.
Huang Y , Gou J , Jia Z , Yang L , Sun Y , Xiao X , Song F , Luo K. Molecular cloning and characterization of two genes encoding dihydroflavonol-4-reductase from Populus trichocarpa. PLoS One 2012;7:e30364.
Hughes NM , Reinhardt K , Field TS , Gerardi AR , Smith W.K. Association between winter anthocyanin production and drought stress in angiosperm evergreen species. J. Exp. Bot. 2010;61:16991709.
Ishida T , Hattori S , Sano R , Inoue K , Shirano Y , Hayashi H , Shibata D , et al. Arabidopsis TRANSPARENT TESTA GLABRA2 is directly regulated by R2R3 MYB transcription factors and is involved in regulation of GLABRA2 transcription in epidermal differentiation. Plant Cell 2007;19:25312543.
Jaakola L , Poole M , Jones MO , Kmri nen-Karppinen T , Koskimki JJ , Hohtola A , Hggman H , et al. A SQUAMOSA MADS box gene involved in the regulation of anthocyanin accumulation in bilberry fruits. Plant Physiol. 2010;153:16191629.
Jagtap UB , Gurav RG , Bapat V.A. Role of RNA interference in plant improvement. Naturwissenschaften 2011;98:473492.
Jiang F , Wang JY , Jia HF , Jia WS , Wang HQ , Xiao M. RNAi-mediated silencing of the flavanone 3-hydroxylase gene and its effect on flavonoid biosynthesis in strawberry fruit. J. Plant Growth Regul. 2012;32:182190. doi:10.1007/s00344012-92891.
Johnson CS , Kolevski B , Smyth D.R. TRANSPARENT TESTA GLABRA2, a trichome and seed coat development gene of Arabidopsis, encodes a WRKY transcription factor. Plant Cell 2002;14:13591375.
Juszczuk IM , Wiktorowska A , Malusa E , Rychter A.M. Changes in the concentration of phenolic compounds and exudation induced by phosphate deficiency in bean plants (Phaseolus vulgaris L.). Plant Soil 2004;267:4149.
Kalimoorthy S , Rao A.S. Effect of salinity on anthocyanin accumulation in the root of maize. Ind. J. Plant Physiol. 1994;37:169170.
Kumar V , Yadav S.K. Overexpression of CsDFR and CsANR enhanced flavonoids accumulation and antioxidant potential of roots in tobacco. Plant Root 2013;7:6576.
Lalusin A , Nishita K , Kim S , Ohta M , Fujimura T. A new MADS-box gene (IbMADS10) from sweet potato (Ipomoea batatas (L.) Lam) is involved in the accumulation of anthocyanin. Mol. Genet. Genomics 2006;275:4454.
Lee XZ , Liang YR , Chen H , Lu JL , Liang HL , Huang FP , Mamati E.G. Alleviation of UV-B stress in Arabidopsis using tea catechins. Afr. J. Biotechnol. 2008;7:41114115.
Lepiniec L , Debeaujon I , Routaboul J , Baudry A , Pourcel L , Nesi N , Caboche M. Genetics and biochemistry of seed flavonoids. Annu. Rev. Plant Biol. 2006;57:405430.
Lillo C , Lea US , Ruoff P. Nutrient depletion as a key factor for manipulating gene expression and product formation in different branches of the flavonoid pathway. Plant Cell Environ. 2008;31:587601.
Liu M , Li X , Liu Y , Cao B. Regulation of flavanone 3-hydroxylase gene involved in the flavonoid biosynthesis pathway in response to UV-B radiation and drought stress in the desert plant, Reaumuria soongorica. Plant Physiol. Biochem. 2013;73:161167.
Lvdal T , Olsen KM , R Slimestad , M.C. Lillo Synergetic effects of nitrogen depletion, temperature, and light on the content of phenolic compounds and gene expression in leaves of tomato. Phytochemistry 2010;71:605613.
Lukaszewicz M , Matysiak-Kara I , Skala J , Fecka I , Cisowski W , Szopa J. Antioxidant capacity manipulation in transgenic potato tuber by changes in phenolic compounds content. J. Agric. Food Chem. 2002;52:15261533.
Luo P , Shen Y , Jin S , Huang S , Cheng X , Wang Z. Overexpression of Rosa rugosa anthocyanin reductase enhances tobacco tolerance to abiotic stress through increased ROS scavenging and modulation of ABA signaling. Plant Sci. 2016;245:3549.
Mahajan M , Ahuja PS , Yadav S.K. Post-transcriptional silencing of flavonol synthase mRNA in tobacco leads to fruits with arrested seed set. PLoS One 2011b;6:e28315.
Mahajan M , Joshi R , Gulati A , Yadav S.K. Increase in flavan-3-ols by silencing flavonol synthase mRNA affects the transcript expression and activity levels of antioxidant enzymes in tobacco. Plant Biol. 2012;14:725733. doi:10.1111/j.14388677.2011.00550.x.
Mahajan M , Kumar V , Yadav S.K. Effect of flavonoid-mediated free IAA regulation on growth and development of in vitro-grown tobacco seedlings. Intern. J. Plant Dev. Biol. 2011;5:4248.
Mahajan M , Yadav S.K. Overexpression of a tea flavanone 3-hydroxylase gene confers tolerance to salt stress and Alternaria solani in transgenic tobacco. Plant Mol. Biol. 2014;85:551573.
Mehrtens F , Kranz H , Bednarek P , Weisshaar B . The Arabidopsis transcription factor MYB12 is a flavonol-specific regulator of phenylpropanoid biosynthesis. Plant Physiol. 2005;138:10831096.
Meng C , Zhang S , Deng YS , Wang GD , Kong F.Y. Overexpression of a tomato flavanone 3-hydroxylase-like protein gene improves chilling tolerance in tobacco. Plant Physiol. Biochem. 2015;96:388400.
237 Michalak A. Phenolic compounds and their antioxidant activity in plants growing under heavy metal stress. Pol. J. Environ. Stud. 2006;15:523530.
Mizutani M , Tsuda S , Suzuki K , Nakamura N , Fukui Y , Kusumi T , Tanaka Y. Evaluation of post transcriptional gene silencing methods using flower color as the indicator. Plant Cell Physiol. 2003;44:S122.
Mpoloka S.W. Effects of prolonged UV-B exposure in plants. Afr. J. Biotechnol. 2008;7:48744883.
Nakamura N , Fukuchi-Mizutani M , Suzuki K , Miyazaki K , Tanaka Y. RNAi suppression of the anthocyanidin synthase gene in Torenia hybrida yields white flowers with higher frequency and better stability than antisense and sense suppression. Plant Biotechnol. 2006;23:1317.
Nakayama T , Yonekura-Sakakibara K , Sato T , Kikuchi S , Fukui Y , Fukuchi-Mizutani M , Ueda T , et al. Aureusidin synthase: A polyphenol oxidase homolog responsible for flower coloration. Science 2000;290:11631166.
Nesi N , Debeaujon I , Jond C , Pelletier G , Caboche M , Lepiniec L. The TT8 gene encodes a basic helix-loop-helix domain protein required for expression of DFR and BAN genes in Arabidopsis siliques. Plant Cell 2000;12:18631878.
Nguyen NH , Kim JH , Kwon J , Jeong CY , Lee W , Lee D , Hong SW , Lee H. Characterization of Arabidopsis thaliana flavonol synthase 1 (FLS1)-overexpression plants in response to abiotic stress. Plant Physiol. Biochem. 2016;103:133142.
Oh MM , Trick HN , Rajashekar C.B. Secondary metabolism and antioxidants are involved in environmental adaptation and stress tolerance in lettuce. J. Plant Physiol. 2009;166:180191.
Pang YP , Peel GJ , Wright E , Wang Z , Dixon R.A. Early steps in proanthocyanidin biosynthesis in the model legume Medicago truncatula. Plant Physiol. 2007;145:601615.
Peng M , Hudson D , Schofield A , Tsao R , Yang R , Gu H , Bi YM , Rothstein S.J. Adaptation of Arabidopsis to nitrogen limitation involves induction of anthocyanin synthesis which is controlled by the NLA gene. J. Exp. Bot. 2008;59:29332944.
Reddy AM , Reddy VS , Scheffler BE , Wienand U , Reddy A.R. Novel transgenic rice overexpressing anthocyanin synthase accumulates a mixture of flavonoids leading to an increased antioxidant potential. Metab. Eng. 2007;9:95111.

Rice-Evans CA , Miller NJ , Paganga G. Structure-antioxidant activity relationships of flavonoids and phenolic acids. Free Radic. Biol. Med. 1996;20:933956.

Rivero RM , Ruiz JM , Garcia PC , Lopez-Lefebre LR , Sanchez E , Romero L. Resistance to cold and heat stress: Accumulation of phenolic compounds in tomato and watermelon plants. Plant Sci. 2001;160:315321.

Ryan KG , Hunt J.E. The effect of UVB radiation on temperate southern hemisphere forests. Environ. Pollut. 2005;137:415427.

Sadik CD , Sies H , Schewe T. Inhibition of 15-lipoxygenases by flavonoids: Structure-activity relations and mode of action. Biochem. Pharmacol. 2003;65:773781.

Sagasser M , Lu GH , Hahlbrock K , Weisshaar B. A. thaliana TRANSPARENT TESTA 1 is involved in seed coat development and defines the WIP subfamily of plant zinc finger proteins. Genes Dev. 2002;16:138149.

Schaart JG , Dubos C , De La Fuente IR , van Houwelingen AM , De Vos RC , Jonkar HH , Xu W , Routaboul JM , Lepiniec L , Bovy A.G. Identification and characterization of MYB-BHLH-WD40 regulatory complexes controlling proanthocyanidin biosynthesis in strawberry (Fragaria x ananassa) fruits. New Phytol. 2012;197:454467.

Schenke D , Bttcher C , Scheel D. Crosstalk between abiotic ultraviolet-B stress and biotic (flg22) stress signaling in Arabidopsis prevents flavonol accumulation in favor of pathogen defense compound production. Plant Cell Environ. 2011;34:18491864.

Schroder J. Probing plant polyketide biosynthesis. Nat. Struct. Biol. 1999;6:714716.

Sompornpailin K , Makita Y , Yamazaki M , Saito K. A WD-repeat-containing putative regulatory protein in anthocyanin biosynthesis in Perilla frutescens. Plant Mol. Biol. 2002;50:485495.

Song X , Diao J , Ji J , Wang G , Guan C , Jin C. Molecular cloning and identification of a flavanone 3-hydroxylase gene from Lycium chinense, and its overexpression enhances drought stress in tobacco. Plant Physiol. Biochem. 2016;98:89100.

Stracke R , Ishihara H , Huep G , Barsch A , Mehrtens F , Niehaus K , Weisshaar B. Differential regulation of closely related R2R3-MYB transcription factors controls flavonol accumulation in different parts of the Arabidopsis thaliana seedling. Plant J. 2007;50:660677.

Suzuki H , Nakayama T , Yonekura-Sakakibara K , Fukui Y , Nakamura N , Yamaguchi MA , Tanaka Y , Kusumi T , Nishino T. cDNA cloning, heterologous expressions, and functional characterization of malonyl-coenzyme A: Anthocyanidin 3-O-glucoside-6-O-malonyltransferase from dahlia flowers. Plant Physiol. 2002;130:21422151.

Takahashi H , Hayashi M , Goto F , Sato S , Soga T , Nishioka T , Tomita M , Yamada M , Uchimiya H. Evaluation of metabolic alteration in transgenic rice overexpressing dihydroflavonol-4-reductase. Ann. Bot. 2006;98:819825.

Tamagnone L , Merida A , Stacey N , Plaskitt K , Parr A , Chang CF , Lynn D , Dow JM , Roberts K , Martin C. Inhibition of phenolic acid metabolism results in precocious cell death and altered cell morphology in leaves of transgenic tobacco plants. Plant Cell 1998;10:18011816.

Tanner GJ , Francki KT , Abrahams S , Watson JM , Larkin PJ , Ashton A.R. Proanthocyanidin biosynthesis in plants: Purification of legume leucoanthocyanidin reductase and molecular cloning of its cDNA. J. Biol. Chem. 2003;278:3164731656.

Tomasi N , Weisskopf L , Renella G , Landi L , Pinton R , Varanini Z , Nannipieri P , Torrent J , Martinola E , Cesco S. Flavonoids of white lupin roots participate in phosphorus mobilization from soil. Soil Biol. Biochem. 2008;40:19711974.

Uhde-Stone C , Liu J , Zinn KE , Allan DL , Vance C.P. Transgenic proteoid roots of white lupin: A vehicle for characterizing and silencing root genes involved in adaptation to P stress. Plant J. 2005;44:840853.

Van Oosten MJ , Sharkhuu A , Batelli G , Bressan RA , Maggio A. The Arabidopsis thaliana mutant air1 implicates SOS3 in the regulation of anthocyanins under salt stress. Plant Mol. Biol. 2013;83:405415.

Verhoeyen ME , Bovy A , Collins G , Muir S , Robinson S , De Vos Chr , Colliver S. Increasing antioxidant levels in tomatoes through modification of the flavonoid biosynthetic pathway. J. Exp. Bot. 2002;53:20992106.

Vernoud V , Laigle G , Rozier F , Meeley R , Perez P , Rogowsky P.M. The HD-ZIP IV transcription factor OCL4 is necessary for trichome patterning and anther development in maize. Plant J. 2009;59:883894.

238 Vom Endt D , Kijne JW , Memelink J. Transcription factors controlling plant secondary metabolism: What regulates the regulators? Phytochemistry 2002;61:107114.

Wade HK , Sohal AK , Jenkins G.J. Arabidopsis ICX1 is a negative regulator of several pathways regulating flavonoid biosynthesis genes. Plant Physiol. 2003;131:707715.

Wahid A , Ghazanfar A. Possible involvement of some secondary metabolites in salt tolerance of sugarcane. J. Plant Physiol. 2006;163:723730.

Wang F , Kong W , Wong G , Fu L , Peng R , Li Z. AtMYB12 regulates flavonoids accumulation and abiotic stress tolerance in transgenic Arabidopsis thaliana. Mol. Genet. Genom. 2016;291:15451559.

Wang H , Fan W , Li H , Yang J , Huang J , Zhang P. Functional characterization of dihydroflavonol-4-reductase in anthocyanin biosynthesis of purple sweet potato underlies the direct evidence of anthocyanins function against abiotic stresses. PLoS One 2013;8:e78484.

Wang Y , Chen S , Oliver Y.u. Metabolic engineering of flavonoids in plants and microorganisms. Appl. Microbiol. Biotechnol. 2011;91:949956.

Winkel B.S.J. The biosynthesis of flavonoids. In: Grotewold E (ed.). The Science of Flavonoids. Springer Science and Business Media, New York, 2006, pp. 7196.

Wu J , Du G , Chen J , Zhou J. Enhancing flavonoid production by systematically tuning the central metabolic pathways based on a CRISPR interference system in Escherichia coli. Sci. Rep. 2015;5:13477. doi:10.1038/srep13477.

Xie DY , Sharma SB , Dixon RA . Anthocyanidin reductase from Medicago truncatula and Arabidopsis thaliana. Arch. Biochem. Biophys. 2004;422:91102.

Xie DY , Sharma SB , Wright E , Wang ZY , Dixon R.A. Metabolic engineering of proanthocyanidins through co-expression of anthocyanidin reductase and the PAP1 MYB transcription factor. Plant J. 2006;45:895907.

Xie DY , Sharma SB , Paiva NL , Ferreira D , Dixon R.A. Role of anthocyanidin reductase, encoded by BANYULS in plant flavonoid biosynthesis. Science 2003;299:396399.

Yoshida K , Iwasaka R , Kaneko T , Sato S , Tabata S , Sakuta M. Functional differentiation of Lotus japonicus TT2s, R2R3-MYB transcription factors comprising a multigene family. Plant Cell Physiol. 2008;49:157169.

Yu O , McGonigle B. Metabolic engineering of isoflavone biosynthesis. Adv. Agron. 2005;86:147190.

Yuan L , Wang L , Han Z , Jiang Y , Zhao L , Liu H , Yang L , Luo K. Molecular cloning and characterization of PtrLAR3, a gene encoding leucoanthocyanidin reductase from Populus trichocarpa, and its constitutive expression enhances fungal resistance in transgenic plants. J. Exp. Bot. 2012;63:25132524.

Zuk M , Prescha A , Stryczewska M , Szopa J. Engineering flax plants to increase their antioxidant capacity and improve oil composition and stability. J. Agric. Food Chem. 2012;60:50035012.

The Role of Gamma Aminobutyric Acid (GABA) During Abiotic Stress in Plants

Abeles, F. B. (1973). Regulation of ethylene production by internal, environmental and stress factors In: Ethylene in Plant Biology (p. 83), Academic Press, New York.

Abeles F. B. , Morgan P. and Saltveit M. (1992). Ethlene in Plant Biology, 2nd ed. Academic Press, New York.

Aurisano, N. , Bertani, A. and Reggiani, R. (1995). Anaerobic accumulation of 4-aminobutyrate in rice seedlings; causes and significance. Phytochemistry, 38, 11471150.

Bai, Q. , Yang, R. , Zhang, L. and Gu, Z. (2013). Salt stress induces accumulation of -aminobutyric acid in germinated foxtail millet (Setaria italica L.). Cereal Chemistry, 90, 145149.

Baum, G. , Chen, Y. , Arazi, T. , Takatsuji, H. and Fromm, H. (1993). A plant glutamate decarboxylase containing a calmodulin binding domain. Cloning, sequence, and functional analysis. Journal of Biological Chemistry, 268, 1961019617.

Baum, G. , Lev-Yadun, S. , Fridmann, Y. , Arazi, T. , Katsnelson, H. , Zik, M. and Fromm, H. (1996). Calmodulin binding to glutamate decarboxylase is required for regulation of glutamate and GABA metabolism and normal development in plants. The EMBO Journal, 15, 29882996.

Bolarn, M. C. , Santa-Cruz, A. , Cayuela, E. and Prez-Alfocea, F. (1995). Short-term solute changes in leaves and roots of cultivated and wild tomato seedlings under salinity. Journal of Plant Physiology, 147, 463468.

Bor, M. , Seckin, B. , Ozgur, R. , Ylmaz, O. , Ozdemir, F. and Turkan, I. (2009). Comparative effects of drought, salt, heavy metal and heat stresses on gamma-aminobutyric acid levels of sesame (Sesamum indicum L.). Acta Physiologiae Plantarum, 31, 655659.

Bouch, N. , Fait, A. , Bouchez, D. , Mller, S. G. and Fromm, H. (2003). Mitochondrial succinic-semialdehyde dehydrogenase of the -aminobutyrate shunt is required to restrict levels of reactive oxygen intermediates in plants. Proceedings of the National Academy of Sciences, 100, 68436848.

Bouch, N. and Fromm, H. (2004). GABA in plants: just a metabolite? Trends in Plant Science, 9, 110115.

Cholewa, E. , Cholewinski, A. J. , Shelp, B. J. , Snedden, W. A. and Bown, A. W. (1997). Cold-shock-stimulated -aminobutyric acid synthesis is mediated by an increase in cytosolic Ca2+, not by an increase in cytosolic H+ . Canadian Journal of Botany, 75, 375382.

Crawford, L. A. , Bown, A. W. , Breitkreuz, K. E. and Guinel, F. C. (1994). The synthesis of [gamma]-aminobutyric acid in response to treatments reducing cytosolic pH. Plant Physiology, 104, 865871.

Du, H. , Wang, Z. , Yu, W. , Liu, Y. and Huang, B. (2011). Differential metabolic responses of perennial grass Cynodon transvaalensisCynodon dactylon (C4) and Poa pratensis (C3) to heat stress. Physiologia Plantarum, 141, 251264.

Fait, A. , Yellin, A. and Fromm, H. (2005). GABA shunt deficiencies and accumulation of reactive oxygen intermediates: insight from Arabidopsis mutants. FEBS Letters, 579, 415420.

Fait, A. , Yellin, A. and Fromm, H. (2006). GABA and GHB neurotransmitters in plants and animals neuronal aspects of plant life. In: Communication in Plants (pp. 171185), Baluka, F. , Mancuso, S. and Volkmann D. (Eds.), Springer-Verlag, Germany.

Gill, S. S. and Tuteja, N. (2010). Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiology and Biochemistry, 48, 909930.

Jaffe, M. J. (1973). Thigmomorphogenesis: The response of plant growth and development to mechanical stimulation: With special reference to Bryoria dioria. Planta, 114, 143157.

Jaffe, M. J. and Biro, R. (1979). Thigmomorphogenesis, the effect of mechanical perturbation on the growth of plants, with special reference to anatomical changes, the role of ethylene and interaction with other environmental stresses. In: Stress Physiology in Crop Plants (pp. 2569), Mussell, H . and Staples, R. C. . (Eds.), John Wiley and Sons, New York.

Kinnersley, A. M. and Turano, F. J. (2000). Gamma aminobutyric acid (GABA) and plant responses to stress. Critical Reviews in Plant Sciences, 19, 479509.

Kornberg, H. L. (1966). Anaplerotic sequences and their role in metabolism. Essays in Biochemistry, 2, 131.

Li, Z. , Yu, J. , Peng, Y. and Huang, B. (2016). Metabolic pathways regulated by -aminobutyric acid (GABA) contributing to heat tolerance in creeping bentgrass (Agrostis stolonifera). Scientific Reports, 6, 116.

Mayer, R. R. , Cherry, J. H. and Rhodes, D. (1990). Effects of heat shock on amino acid metabolism of cowpea cells. Plant Physiology, 94, 796810.

Morgan, P. W. and Drew, M. C. (1997). Ethylene and plant responses to stress. Physiologia Plantarum, 100, 620630.

Nayyar, H. , Kaur, R. , Kaur, S. and Singh, R. (2014). -Aminobutyric acid (GABA) imparts partial protection from heat stress injury to rice seedlings by improving leaf turgor and upregulating osmoprotectants and antioxidants. Journal of Plant Growth Regulation, 33, 408419.

248 Palanivelu, R. , Brass, L. , Edlund, A. F. and Preuss, D. (2003). Pollen tube growth and guidance is regulated by POP2, an Arabidopsis gene that controls GABA levels. Cell, 114, 4759.

Raggi, V. (1994). Changes in free amino acids and osmotic adjustment in leaves of waterstressed bean. Physiologia Plantarum, 91, 427434.

Ramakrishna, A. and Ravishankar, G. A. (2011). Influence of abiotic stress signals on secondary metabolites in plants. Plant Signaling and Behavior, 6, 17201731.

Ramakrishna, A. and Ravishankar, G. A. (2013) Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Climate Change and Plant Abiotic Stress Tolerance (pp. 705726), Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany.

Ramputh, A. I. and Bown, A. W. (1996). Rapid [gamma]-aminobutyric acid synthesis and the inhibition of the growth and development of oblique-banded leaf-roller larvae. Plant Physiology, 111, 13491352.

Recht, L. , Tpfer, N. , Batushansky, A. , Sikron, N. , Gibon, Y. , Fait, A. and Zarka, A. (2014). Metabolite profiling and integrative modeling reveal metabolic constraints for carbon partitioning under nitrogen starvation in the green algae Haematococcus pluvialis. Journal of Biological Chemistry, 289, 3038730403.

Renault, H. , El Amrani, A. , Berger, A. , Mouille, G. , SoubigouTaconnat, L. , Bouchereau, A. and Deleu, C. (2013). Aminobutyric acid transaminase deficiency impairs central carbon metabolism and leads to cell wall defects during salt stress in Arabidopsis roots. Plant, Cell and Environment, 36, 10091018.

Scholz, S. S. , Malabarba, J. , Reichelt, M. , Heyer, M. , Ludewig, F. and Mithfer, A. (2017). Evidence for GABA-induced systemic GABA accumulation in Arabidopsis upon wounding. Frontiers in Plant Science, 8, 19.

Shelp, B. J. , Bown, A. W. and McLean, M. D. (1999). Metabolism and functions of gamma-aminobutyric acid. Trends in Plant Science, 4, 446452.

Snedden, W. A. and Fromm, H. (1999). Regulation of the -aminobutyrate-synthesizing enzyme, glutamate decarboxylase, by calcium-calmodulin: a mechanism for rapid activation in response to stress. In: Plant Responses to Environmental Stresses: From Phytohormones to Genome Reorganization (pp. 549574), Lerner, H. R. . (Ed.), Marcel Dekker, New York.

Streeter, J. G. and Thompson, J. F. (1972). Anaerobic accumulation of gamma-aminobutyric acid and alanine in radish leaves (Raphanus sativus, L.). Plant Physiology, 49, 572578.
Thompson, J. F. , Stewart, C. R. and Morris, C. J. (1966). Changes in amino acid content of excised leaves during incubation I. The effect of water content of leaves and atmospheric oxygen level. Plant Physiology, 41, 15781584.
Tsushida, T. and Murai, T. (1987). Conversion of glutamic acid to -aminobutyric acid in tea leaves under anaerobic conditions. Agricultural and Biological Chemistry, 51, 28652871.
Wallace, W. , Secor, J. and Schrader, L. E. (1984). Rapid accumulation of -aminobutyric acid and alanine in soybean leaves in response to an abrupt transfer to lower temperature, darkness, or mechanical manipulation. Plant Physiology, 75, 170175.
Woodrow, P. , Ciarmiello, L. F. , Annunziata, M. G. , Pacifico, S. , Iannuzzi, F. , Mirto, A. and Carillo, P. (2017). Durum wheat seedling responses to simultaneous high light and salinity involve a fine reconfiguration of amino acids and carbohydrate metabolism. Physiologia Plantarum, 159, 290312.

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Aung B , Gruber MY , Hannoufa A. The MicroRNA156 system: A tool in plant biotechnology. Biocatal. Agric. Biotechnol. 2015;4:432442.
Bakhshi BE , Mohseni Fard E , Nikpay N , Ebrahimi MA , Bihamta MR , Mardi M , Salekdeh G.H. MicroRNA signatures of drought signaling in rice root. PLoS ONE 2016;11:e0156814.
Balestrazzi A , Confalonieri M , Don M , Carbonera D. Genotoxic stress, DNA repair, and crop productivity. In: Tuteja N , Gill SS (eds.). Crop Improvement Under Adverse Conditions. Berlin: Springer-Verlag, 2012; pp. 153169.
Balestrazzi A , Confalonieri M , Macovei A , Carbonera D. Seed imbibition in Medicago truncatula Gaertn.: Expression profiles of DNA repair genes in relation to PEG-mediated stress. J. Plant Physiol. 2010;168:706713.
Balestrazzi A , Confalonieri M , Macovei A , Don M , Carbonera D. Genotoxic stress and DNA repair in plants: Emerging functions and tools for improving crop productivity. Plant Cell Rep. 2011;30:287295.
Barlow KM , Christy BP , OLeary GJ , Riffkin PA , Nuttall J.G. Simulating the impact of extreme heat and frost events on wheat crop production: A review. Field Crops Res. 2015;171:109119.
262 Bartel D.P. MicroRNAs: Genomics, biogenesis, mechanism, and function. Cell 2004;116:281297.
Bhuiyan NH , Selvaraj G , Wei Y , King J. Role of lignification in plant defense. Plant Signal. Behav. 2009;4:158159.
Boerjan W , Ralph J , Baucher M. Lignin biosynthesis. Annu. Rev. Plant Biol. 2003;54:519546.
Borek S , Ratajczak W , Ratajczak L. Regulation of storage lipid metabolism in developing and germinating lupin (Lupinus spp.) seeds. Acta Physiol. Plant. 2015;37:119.
Borges F , Martienssen R.A. The expanding world of small RNAs in plants. Nat. Rev. Mol. Cell Biol. 2015;16:727741.
Boudet AM , Kajita S , Grima-Pettenati J , Goffner D. Lignins and lignocellulosics: A better control of synthesis for new and improved uses. Trends Plant Sci. 2003;8:576581.
Boyer J.S. Plant productivity and environment. Science 1982;218:443448.
Cairney J , Pullman G.S. The cellular and molecular biology of conifer embryogenesis. New Phytol. 2007;176:511536.
Cakir OB , Candar-Cakir B , Zhang B. Small RNA and degradome sequencing reveals important microRNA function in Astragalus chrysochlorus response to selenium stimuli. Plant Biotechnol. J. 2016;14:543556.
Capito C , Paiva JAP , Santos DM , Fevereiro P. In Medicago truncatula, water deficit modulates the transcript accumulation of components of small RNA pathways. BMC Plant Biol. 2011;11:79.
Carocho M , Ferreira I.C. The role of phenolic compounds in the fight against cancer A re view. Anticancer Agents Med. Chem. 2013;13:12361258.
Chen H , Chu P , Zhou Y , Li Y , Liu J , Ding Y , Tsang EW , Jiang L , Wu K , Huang S . Overexpression of AtOGG1, a DNA glycosylase/AP lyase, enhances seed longevity and abiotic stress tolerance in Arabidopsis. J. Exp. Bot. 2012;63:41074112.
Chen Q , Li M , Zhang Z , Tie W , Chen X , Jin L , Zhai N , Zheng Q , Wang R , Xu G , Zhang H , Liu P , Zhou H. Integrated mRNA and microRNA analysis identifies genes and small miRNA molecules associated with transcriptional and post-transcriptional-level responses to both drought stress and re-watering treatment in tobacco. BMC Genomics 2017;18:62.
Chibuike GU , Obiora S.C. Heavy metal polluted soils: Effect on plants and bioremediation methods. Appl. Environ. Soil Sci. 2014;2014:112.
Choi D , Ward BL , Bostock R.M. Differential induction and suppression of potato 3-hydroxy-3-methylglutaryl coenzyme A reductase genes in response to Phytophthora infestans and to its elicitor arachidonic acid. Plant Cell 1992;4:13331344.
Chung PJ , Jung H , Jeong DH , Ha SH , Do Choi Y , Kim J.K. Transcriptome profiling of drought responsive noncoding RNAs and their target genes in rice. BMC Genomics 2016;17:563.
Chung PJ , Park BS , Wang H , Liu J. Light-inducible MiR163 targets PXMT1 transcripts to promote seed germination and primary root elongation in Arabidopsis. Plant Physiol. 2016;170:17721782.
Cordoba-Canero D , Roldan-Arjona T , Ariza R.R. Arabidopsis ZDP DNA 30-phosphatase and ARP endonuclease function in 8-oxoG repair initiated by FPG and OGG1 DNA glycosylases. Plant J. 2014;79:824834.
Curaba J , Singh MB , Bhalla P.L. miRNAs in the crosstalk between phytohormone signalling pathways. J. Exp. Bot. 2014;65:14251438.
Czarna M , Kolodziejczak M , Janska H. Mitochondrial proteome studies in seeds during germination. Proteomes 2016;4:19.
Das SS , Karmakar P , Nandi AK , N. Sanan-Mishra Small RNA mediated regulation of seed germination. Front. Plant Sci. 2015;6:828.
Djami-Tchatchou AT , Sanan-Mishra N , Ntushelo K , Dubery I.A. Functional roles of microRNAs in agronomically important plants-potential as targets for crop improvement and protection. Front. Plant Sci. 2017;8:378.
Dolata J , Bajczyk M , Bielewicz D , Niedojadlo K , Niedojadlo J , Pietrykowska H , Walczak W , Szweykowska-Kulinska Z , Jarmolowski A. Salt stress reveals a new role for ARGONAUTE1 in miRNA biogenesis at the transcriptional and posttranscriptional levels. Plant Physiol. 2016;172:297312.
Eljounaidi K , Cankar K , Comino C , Moglia A , Hehn A , Bourgaud F , Bouwmeester H , Menin B , Lanteri S , Beekwilder J. Cytochrome P450s from Cynara cardunculus L. CYP71AV9 and CYP71BL5, catalyze distinct hydroxylations in the sesquiterpene lactone biosynthetic pathway. Plant Sci. 2014;223:5968.
Fan R , Li Y , Li C , Zhang Y. Differential microRNA analysis of glandular trichomes and young leaves in Xanthium strumarium L. reveals their putative roles in regulating terpenoid biosynthesis. PLoS ONE 2015;10:e0139002.
Felekkis K , Touvana E , Stefanou C , Deltas C. microRNAs: A newly described class of encoded molecules that play a role in health and disease. Hippokratia 2010;14:236240.
Ferdous J , Hussain SS , Shi B.J. Role of microRNAs in plant drought tolerance. Plant Biotechnol. J. 2015;13:293305.

Ferreira TH , Gentile A , Vilela RD , Costa GGL , Dias LI , Endres L , Menossi M. microRNAs associated with drought response in the bioenergy crop sugarcane (Saccharum Spp.). PLoS ONE 2012;7:e46703.

Frank G , Pressman E , Ophir R , Althan L , Shaked R , Freedman M , Shen S , Firon N. Transcriptional profiling of maturing tomato (Solanum lycopersicum L.) microspores reveals the involvement of heat shock proteins, ROS scavengers, hormones, and sugars in the heat stress response. J. Exp. Bot. 2009;60:38913908.

Fu Y , Guo H , Cheng Z , Wang R , Li G , Huo G , Liu W. NtNAC-R1, a novel NAC transcription factor gene in tobacco roots, responds to mechanical damage of shoot meristem. Plant Physiol. Biochem. 2013;69:7481.

Galland M , Huguet R , Arc E , Cueff G , Job D , Rajjou L. Dynamic proteomics emphasizes the importance of selective mRNA translation and protein turnover during Arabidopsis seed germination. Mol. Cell. Proteomics 2014;13:252268.

Gao C , Wang P , Zhao S , Zhao C , Xia H , Hou L , Ju Z , Zhang Y , Li C , Wang X. Small RNA profiling and degradome analysis reveal regulation of microRNA in peanut embryogenesis and early pod development. BMC Genomics 2017;18:220.

Gao F , Wang N , Li HY , Liu JS , Fu CX , Xiao ZH , Wei CX , Lu XD , Feng JC , Zhou Y.J. Identification of drought-responsive microRNAs and their targets in Ammopiptanthus mongolicus by using high-throughput sequencing. Sci. Rep. 2016;6:34601.

Gao R , Austin RS , Amyot L , Hannoufa A. Comparative transcriptome investigation of global gene expression changes caused by miR156 overexpression in Medicago sativa. BMC Genomics 2016;17:658.

Gentile A , Dias LI , Mattos RS , Ferreira TH, , Menossi M. MicroRNAs and drought responses in sugarcane. Front Plant Sci. 2015;23(6):58. doi: 10.3389/fpls.2015.00058.

263 Gielen H , Remans T , Vangronsveld J , Cuypers A. MicroRNAs in metal stress: Specific roles or secondary responses? Int. J. Mol. Sci. 2012;13:1582615847.

Guo HS , Xie Q , Fei JF , Chua N.H. MicroRNA directs mRNA cleavage of the transcription factor NAC1 to downregulate auxin signals for Arabidopsis lateral root development. Plant Cell 2005;17:13761386.

Gupta OP , Karkute SG , Banerjee S , Meena NL , Dahuja A. Contemporary understanding of miRNA-based regulation of secondary metabolites biosynthesis in plants. Front. Plant Sci. 2017;8:374.

Gupta OP , Meena NL , Sharma I , Sharma P. Differential regulation of microRNAs in response to osmotic, salt and cold stresses in wheat. Mol. Biol. Rep. 2014;41:46234629.

Han C , Yang P. Studies on the molecular mechanisms of seed germination. Proteomics 2015;15:16711679.

Hatfield JL , Prueger J.H. Temperature extremes: Effect on plant growth and development. Weather Clim. Extremes 2015;10:410.

He D , Wang Q , Wang K , Yang P. Genome-wide dissection of the microRNA expression profile in rice embryo during early stages of seed germination. PloS ONE 2015;10:e0145424.

Hu J , Jin J , Qian Q , Huang K , Ding Y. Small RNA and degradome profiling reveals miRNA regulation in the seed germination of ancient eudicot Nelumbo nucifera. BMC Genomics 2016;17:684.

Huang JH , Qi YP , Wen SX , Guo P , Chen XM , Chen L.S. Illumina microRNA profiles reveal the involvement of miR397a in citrus adaptation to long-term boron toxicity via modulating secondary cell-wall biosynthesis. Sci. Rep. 2016;6:22900.

Huo H , Wei S , Bradford K.J. DELAY OF GERMINATION1 (DOG1) regulates both seed dormancy and flowering time through microRNA pathways. Proc. Natl. Acad. Sci. USA 2016;E2199E2206.

Jia XY , Shen J , Liu H , Li F , Ding N , Gao CY , Pattanaik S , Patra B , Li RZ , Yuan L. Small tandem target mimic-mediated blockage of microRNA858 induces anthocyanin accumulation in tomato. Planta 2015;242:283293.

Jian H , Wang J , Wang T , Wei L , Li J , Liu L. Identification of rapeseed microRNAs involved in early stage seed germination under salt and drought stresses. Front. Plant Sci. 2016;7:658.

Jones-Rhoades MW , Bartel D.P. Computational identification of plant microRNAs and their targets, including a stress-induced miRNA. Mol. Cell 2004;14:787799.

Jones-Rhoades MW , Bartel DP , Bartel B. MicroRNAs and their regulatory roles in plants. Annu. Rev. Plant Biol. 2006;57:1953.

Jossier M , Bouly JP , Meimoun P , Arjmand A , Lessard P , Hawley S , Grahame HD , Thomas M. SnRK1 (SNF1-related kinase1) has a central role in sugar and ABA signalling in Arabidopsis thaliana. Plant J. 2009;59:316328.

Juarez MT , Kui JS , Thomas J , Heller BA , Timmermans M.C. microRNA-mediated repression of rolled leaf1 specifies maize leaf polarity. Nature 2004;428:8488.

Katiyar A , Smita S , Muthusamy SK , Chinnusamy V , Pandey DM , Bansal K.C. Identification of novel drought-responsive microRNAs and trans-acting siRNAs from Sorghum bicolor (L.) Moench by high-throughput sequencing analysis. Front. Plant Sci. 2015;6:506.

Kawaguchi R , Girke T , Bray EA , Bailey-Serres J. Differential mRNA translation contributes to gene regulation under non-stress and dehydration stress conditions in Arabidopsis thaliana. Plant J. 2004;38:823839.

Kayhan DS , Kayhan C , ifti Y . Excess boron responsive regulations of antioxidative mechanism at physio-biochemical and molecular levels in Arabidopsis thaliana. Plant Physiol. Biochem. 2016;109:337345.

Khraiwesh B , Zhu JK , Zhu J. Role of miRNAs and siRNAs in biotic and abiotic stress responses of plants. BBA 2012;1819:137148.

Kim J , Jung JH , Reyes JL , Kim YS , Chung KS , Kim JA , Lee M , Lee Y , Narry Kim V , Chua NH , Park C.M. microRNA-directed cleavage of ATHB15 mRNA regulates vascular development in Arabidopsis inflorescence stems. Plant J. 2005;42:8494.

Kim JY , Lee HJ , Jung HJ , Maruyama K , Suzuki N , Kang H. Overexpression of microRNA395c or 395e affects differently the seed germination of Arabidopsis thaliana under stress conditions. Planta 2010a;232:14471454.

Kim JY , Kwak KJ , Jung HJ , Lee HJ , H. Kang MicroRNA402 affects seed germination of Arabidopsis thaliana under stress conditions via targeting DEMETER-LIKE protein 3 mRNA. Plant Cell Physiol. 2010b;51:10791083.

Koul A , Yogindran S , Sharma D , Kaul S , Rajam MV , Dhar M.K. Carotenoid profiling, in silico analysis and transcript profiling of miRNAs targeting carotenoid biosynthetic pathway genes in different developmental tissues of tomato. Plant Physiol. Biochem. 2016;108:412421.

Kozomara A , Griffiths-Jones S. miRBase: Integrating microRNA annotation and deep-sequencing data. Nucl. Acids Res. 2011;39:D152D157.

Kranner I , Beckett RP , Minibayeva FV , Seal C.E. What is stress? Concepts, definitions and applications in seed science. New Phytol. 2010;188:655673.

Kumar V , Guleria P , Kumar V, Yadav S.K. Gold nanoparticle exposure induces growth and yield enhancement in Arabidopsis thaliana. Sci. Total Environ. 2013;461462:462468.

Li D , Wang L , Liu X , Cui D , Chen T , Zhang H , Jiang C , Xu C , Li P , Li S , Zhao L , Chen H. Deep sequencing of maize small RNAs reveals a diverse set of miroRNA in dry and imbibed seeds. PLoS ONE 2013;8:e55107.

Li FF , Wang WD , Zhao N , Xiao BG , Cao PJ , Wu XF , Ye CY , Shen EH , Qiu J , Zhu QH , Xie JH , Zhou XP , Fan L.J. Regulation of nicotine biosynthesis by an endogenous target mimicry of microRNA in tobacco. Plant Physiol. 2015;169:10621071.

Li S , Castillo-Gonzlez C , Yu B , Zhang X. The functions of plant small RNAs in development and in stress responses. Plant J. 2016; doi:doi:10.1111/tpj.13444.

Li WX , Oono Y , Zhu J , He XJ , Wu JM , Iida K , Lu XY , Cui X , Jin H , Zhu J.K. The Arabidopsis NFYA5 transcription factor is regulated transcriptionally and posttranscriptionally to promote drought resistance. Plant Cell 2008;20:22382251.

Lin HJ , Zhang ZM , Shen YO , Gao SB , Pan G.T. Review of plant miRNAs in environmental stressed conditions. Res. J. Agric. Biol. Sci. 2009;5:803814.
Liu PP , Montgomery TA , Fahlgren N , Kasschau KD , Nonogaki H , Carrington J.C. Repression of AUXIN RESPONSE FACTOR10 by microRNA160 is critical for seed germination and post-germination stages. Plant J. 2007;52:133146.
Liu W , Xu L , Wang Y , Shen H , Zhu X , Zhang K , Chen Y , Yu R , Limera C , Liu L. Transcriptome-wide analysis of chromium-stress responsive microRNAs to explore miRNA-mediated regulatory networks in radish (Raphanus sativus L.). Sci. Rep. 2015;5:14024.
264 Liu Y , El-Kassaby Y.A. Regulatory crosstalk between microRNAs and hormone signaling cascades controls the variation on seed dormancy phenotype at Arabidopsis thaliana seed set. Plant Cell Rep. 2017;36(5):705717. doi:10.1007/s00299-017-2111-6.
Liu Z , Li J , Wang L , Li Q , Lu Q , Yu Y , Li S , Bai MY , Hu Y , Xiang F. Repression of callus initiation by the miRNA-directed interaction of auxin-cytokinin in Arabidopsis thaliana. Plant J. 2016;87:391402.
Lu S , Li Q , Wei H , Chang MJ , Tunlaya-Anukit S , Kim H , Liu J , Song J , Sun YH , Yuan L , Yeh TF , Peszlen I , Ralph J , Sederoff RR , Chiang V.L. Ptr-miR397a is a negative regulator of laccase genes affecting lignin content in Populus trichocarpa. Proc. Natl. Acad. Sci. USA 2013;110:1084810853.
Macovei A , Balestrazzi A , Confalonieri M , Fa M , Carbonera D. New insights on the barrel medic MtOGG1 and MtFPG functions in relation to oxidative stress response in planta and during seed imbibition. Plant Physiol. Biochem. 2011a;49:10401050.
Macovei A , Balestrazzi A , Confalonieri M , Buttafava A , Carbonera D . The TFIIS and TFIIS-like genes from Medicago truncatula are involved in oxidative stress response. Gene 2011b;470:2030.
Macovei A , Garg B , Raikwar S , Balestrazzi A , Carbonera D , Buttafava A , Bremont JF , Gill SS , Tuteja N. Synergistic exposure of rice seeds to different doses of -ray and salinity stress resulted in increased antioxidant enzyme activities and gene-specific modulation of TC-NER pathway. BioMed Res. Int. 2014;2014:676934.
Macovei A , Pagano A , Leonetti P , Carbonera D , Balestrazzi A , Arajo S.S. Systems biology and genome-wide approaches to unveil the molecular players involved in the pre-germinative metabolism: Implications on seed technology traits. Plant Cell Rep. 2017;36(5):669688. doi:10.1007/s00299-016-2060-5.
Macovei A , Tuteja N. Different expression of miRNAs targeting helicases in rice in response to low and high dose rate -ray treatments. Plant Signal. Behav. 2013;8:e25128.
Macovei A , Tuteja N. microRNAs targeting DEAD-box helicases are involved in salinity stress response in rice (Oryza sativa L.). BMC Plant Biol. 2012;12:183.
Maeda S , Sakazono S , Masako-Suzuki H , Taguchi M , Yamamura K , Nagano K , Endo T , Saeki K , Osaka M , Nabemoto M , Ito K , Kudo T , Kobayashi M , Kawagishi M , Fujita K , Nanjo H , Shindo T , Yano K , Suzuki G , Suwabe K , Watanabe M. Comparative analysis of microRNA profiles of rice anthers between cool-sensitive and cool-tolerant cultivars under cool-temperature stress. Genes Genet. Syst. 2016;91:97109.
Mangrauthia SK , Agarwal S , Sailaja B , Madhav MS , Voleti S.R. MicroRNAs and their role in salt stress response in plants. In: Salt Stress in Plants. New York, NY: Springer New York, 2013; pp. 1546.
Martin RC , Liu PP , Goloviznina NA , Nonogaki H. microRNA, seeds, and Darwin?: Diverse function of miRNA in seed biology and plant responses to stress. J. Exp. Bot. 2010;61:22292234.
McCarty KM , Hanh HT , Kim K.W. Arsenic geochemistry and human health in South East Asia. Rev. Environ. Health 2011;26:7178.
Millar AA , Gubler F. The Arabidopsis GAMYB-like genes, MYB33 and MYB65, are microRNA-regulated genes that redundantly facilitate anther development. Plant Cell 2005;17:705721.
Min Yang Z , Chen J. A potential role of microRNAs in plant response to metal toxicity. Metallomics 2013;5:1184.
Mittal D , Sharma N , Sharma V , Sopory SK , Sanan-Mishra N. Role of microRNAs in rice plant under salt stress. Ann. Appl. Biol. 2016;168:218.
Morin RD , Aksay G , Dolgosheina E , Ebhardt HA , Magrini V , Mardis ER , Sahinalp SC , Unrau PJ . Comparative analysis of the small RNA transcriptomes of Pinus contorta and Oryza sativa. Genome Res. 2008;18:571584.
Nakashima K , Yamaguchi-Shinozaki K , Shinozaki K. The transcriptional regulatory network in the drought response and its crosstalk in abiotic stress responses including drought, cold, and heat. Front. Plant Sci. 2014;5:170.
Nambara E , Okamoto M , Tatematsu K , Yano R , Seo M , Kamiya Y. Abscisic acid and the control of seed dormancy and germination. Seed Sci. Res. 2010;20:55.
Nguyen HN , Kim JH , Hyun WY , Nguyen NT , Hong SW , Lee H. TTG1-mediated flavonols biosynthesis alleviates root growth inhibition in response to ABA. Plant Cell Rep. 2013;32:503514.
Niu J , Wang J , Hu H , Chen Y , An J , Cai J , Sun R , Sheng Z , Liu X , Lin S. Cross-talk between freezing response and signaling for regulatory transcriptions of MIR475b and its targets by miR475b promoter in Populus suaveolens. Sci Rep. 2016;6:20648.
Nodine MD , Bartel D.P. MicroRNAs prevent precocious gene expression and enable pattern formation during plant embryogenesis. Genes Dev. 2010;24:26782692.
Noman A , Aqeel M. miRNA-based heavy metal homeostasis and plant growth. Environ. Sci. Pollut. Res. 2017;24(11):1006810082. doi:10.1007/s11356-017-8593-5.
Nonogaki H. Repression of transcription factors by microRNA during seed germination and postgermination. Plant Signal. Behav. 2008;3:6567.
Ooka H , Satoh K , Doi K , Nagata T , Otomo Y , Murakami K , Matsubara K , Osato N , Kawai J , Carninci P , Havashizaki Y , Kojima K , Takahara Y , Kikuchi S. Comprehensive analysis of NAC family genes in Oryza sativa and Arabidopsis thaliana. DNA Res. 2003;10:239247.
Ortega-Galisteo AP , Morales-Ruiz T , Ariza RR , Roldn-Arjona T. Arabidopsis DEMETER-LIKE proteins DML2 and DML3 are required for appropriate distribution of DNA methylation marks. Plant Mol. Biol. 2008;67:671681.
Panda SK , Sunkar R. Nutrient- and other stress-responsive microRNAs in plants: Role for thiol-based redox signaling. Plant Signal. Behav. 2015;10:e1010916.
Pang M , Woodward AW , Agarwal V , Guan X , Ha M , Ramachandran V , Chen X , Triplett BA , Stelly DM , Chen Z.J. Genome wide analysis reveals rapid and dynamic changes in miRNA and siRNA sequence and expression during ovule and fiber development in allotetraploid cotton (Gossypium hirsutum L.). Genome Biol. 2009;10:R122.
Pani A , Mahapatra R.K. Computational identification of microRNAs and their targets in Catharanthus roseus expressed sequence tags. Genomics Data 2013;1:26.
Paparella S , Araujo SS , Rossi G , Wijayasinghe M , Carbonera D , Balestrazzi A. Seed priming: State of the art and new perspectives. Plant Cell Rep. 2015;34:12811293.
Park HJ , Kim WY , Yun D.J. A new insight of salt stress signaling in plant. Mol. Cells 2016;39:447459.
Parreira JR , Branco D , Almeida AM , Czubacka A , Agacka-Modoch M , Paiva JAP , Tavares-Cadete F , Arajo S.S. Systems biology approaches to improve drought stress tolerance in plants: State of the art and future challenges. In: Hossain MA , Wani SH , Bhattacharjee S , Burritt DJ , Tran LSP (eds.). Drought 265Stress Tolerance in Plants Vol 2: Molecular and Genetic Perspectives. Cham, Switzerland: Springer International Publishing, 2016; pp. 433471.

Penfield S , Pinfield-Wells H , Graham I.A. Lipid metabolism in seed dormancy. In: Bradford KJ , Nonogaki H (eds.). Annual Plant Reviews Volume 27: Seed Development, D ormancy and Germination. Oxford, UK: Blackwell Publishing Ltd, 2007.

Ragupathy R , Ravichandran S , Mahdi MSR , Huang D , Reimer E , Domaratzki M , Cloutier S. Deep sequencing of wheat sRNA transcriptome reveals distinct temporal expression pattern of miRNAs in response to heat, light and UV. Sci. Rep. 2016;6:39373.

Rajjou L , Balghazi M , Huguet R , Robin C , Moreau A , Job C , Job D. Proteomic investigation of the effect of salicylic acid on Arabidopsis seed germination and establishment of early defense mechanisms. Plant Physiol. 2006;141:910923.

Rajjou L , Belghazi M , Huguet R , Og L , Bourdais G , Bove J , Collet B , Godin B , Granier F , Boutin JP , Job D , Jullien M , Grappin P. Protein repair L-isoaspartyl methyltransferase 1 is involved in both seed longevity and germination vigor in Arabidopsis. Plant Cell 2008;20:30223037.

Rajjou L , Debeaujon I. Seed longevity: Survival and maintenance of high germination ability of dry seeds. CR Biol. 2008;331:796805.

Ramakrishna A , Ravishankar G.A. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal. Behav. 2011;6:17201731.

Ramakrishna A , Ravishankar G.A. Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Tuteja N , Gill SS (eds.). Climate Change and Abiotic Stress Tolerance. Weinheim: Wiley-VCH, 2013. ISBN 978-3-527-33491-9.

Ranocha P , McDougall G , Hawkins S , Sterjiades R , Borderies G , Stewart D , Cabanes-Macheteau M , Boudet AM , Goffner D. Biochemical characterization, molecular cloning and expression of laccases a divergent gene family in poplar. Eur. J. Biochem. 1999;259:485495.

Reyes LJ , Chua N.H. ABA induction of miR159 controls transcript levels of two MYB factors during Arabidopsis seed germination. Plant J. 2007;49:592606.

Rubinelli PM , Chuck G , Li X , Meilan R. Constitutive expression of the Corngrass1 microRNA in poplar affects plant architecture and stem lignin content and composition. Biomass Bioenerg. 2013;54:312321.

Samad AFA , Sajad M , Nazaruddin N , Fauzi IA , Murad AMA , Zainal Z , I. Ismail MicroRNA and transcription factors: Key players in plants regulatory network. Front. Plant Sci. 2017;8:565. doi:10.3389/fpls.2017.00565.

Schilmiller AL , Stout J , Weng JK , Humphreys J , Ruegger MO , Chapple C. Mutations in the cinnamate 4-hydroxylase gene impact metabolism, growth and development in Arabidopsis. Plant J. 2009;60:771782.

Shanker AK , Djanaguiraman M , Venkateswarlu B. Chromium interactions in plants: Current status and future strategies. Metallomics 2009;1:375.

Sharmin SA , Alam I , Kim KH , Kim YG , Kim PJ, , Bahk JD , Lee B.H. Chromium-induced physiological and proteomic alterations in roots of Miscanthus sinensis. Plant Sci. 2012;187:113126.

Sharma D , Tiwari M , Lakhwani D , Tripathi RD , Trivedi P.K. Differential expression of microRNAs by arsenate and arsenite stress in natural accessions of rice. Metallomics 2015;7:174187.

Sharma D , Tiwari M , Pandey A , Bhatia C , Sharma A , Trivedi P.K. MicroRNA858 is a potential regulator of phenylpropanoid pathway and plant development. Plant Physiol. 2016;171:944959.

Shen EM , Singh SK , Ghosh JS , Patra B , Paul P , Yuan L , Pattanaik S. The miRNAome of Catharanthus roseus: Identification, expression analysis, and potential roles of microRNAs in regulation of terpenoid indole alkaloid biosynthesis. Sci. Rep. 2017;7:43027.

Shi MZ , Xie D.Y. Biosynthesis and metabolic engineering of anthocyanins in Arabidopsis thaliana. Recent Pat. Biotechnol. 2014;8:4760.

Shriram V , Kumar V , Devarumath RM , Khare TS , Wani S.H. MicroRNAs as potential targets for abiotic stress tolerance in plants. Front. Plant Sci. 2016;7:817.

Shrivastava P , Kumar R. Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. Saudi J. Biol. Sci. 2015;22:123131.

Singh N , Srivastava S , Shasany AK , Sharma A. Identification of miRNAs and their targets involved in the secondary metabolic pathways of Mentha spp. Comput. Biol. Chem. 2016;64:154162.

Song G , Zhang R , Zhang S , Li Y , Gao J , Han X , Chen M , Wang J , Li W , Li G. Response of microRNAs to cold treatment in the young spikes of common wheat. BMC Genomics 2017;18:212.

Song JB , Gao S , Sun D , Li H , Shu XX , Yang Z.M. miR394 and LCR are involved in Arabidopsis salt and drought stress responses in an abscisic acid-dependent manner. BMC Plant Biol. 2013;13:210.

Song JB , Gao S , Wang Y , Li BW , Zhang YL , Yang Z.M. miR394 and its target gene LCR are involved in cold stress response in Arabidopsis. Plant Gene 2016;5:5664.

Song JB , Huang SQ , Dalmay T , Yang Z.M. Regulation of leaf morphology by microRNA394 and its target LEAF CURLING RESPONSIVENESS. Plant Cell Physiol. 2012;53:12831294.

Stasolla C , Loukanina N , Ashihara H , Yeung EC , Trevor A.T. Changes in pyrimidine nucleotide biosynthesis during germination of white spruce (Picea glauca) somatic embryos. In Vitro Cell Dev. Biol. Plant 2001;37:285292.

Sun Y , Qiu Y , Duan M , Wang J , Zhang X , Wang H , Song J , Li X. Identification of anthocyanin biosynthesis related microRNAs in a distinctive Chinese radish (Raphanus sativus L.) by high-throughput sequencing. MGG 2017;292:215229.

Sunkar R , Li YF , Jagadeeswaran G. Functions of microRNAs in plant stress responses. Trends Plant Sci. 2012;17:196203.

Sunkar R , Zhu J.K. Novel and stress-regulated microRNAs and other small RNAs from Arabidopsis. Plant Cell 2004;16:20012019.

Tanaka Y , Sasaki N , Ohmiya A. Biosynthesis of plant pigments: Anthocyanins, betalains and carotenoids. Plant J. 2008;54:733749.

Trindade I , Capito C , Dalmay T , Fevereiro MP , Dos Santos D.M. miR398 and miR408 are up-regulated in response to water deficit in Medicago truncatula. Planta 2010;231:705716.

Tsuji H , Aya K , Ueguchi-Tanaka M , Shimada Y , Nakazono M , Watanabe R , Nishizawa NK , Gomi K , Shimada A , Kitano H , Ashikari M , Matsuoka M. GAMYB controls different sets of genes and is differentially regulated by microRNA in aleurone cells and anthers. Plant J. 2006;47:427444.

Vanholme R , Ralph J , Akiyama T , Lu F , Pazo JR , Kim H , Christensen JH , Van Reusel B , Storme V , De Rycke R , Rohde A , Morreel K , Boerjan W. Engineering traditional 266monolignols out of lignin by concomitant up-regulation of F5H1 and down-regulation of COMT in Arabidopsis. Plant J. 2010;64:885897.

Vashisht I , Mishra P , Pal T , Chanumolu S , Singh TR , Chauhan R.S. Mining NGS transcriptomes for miRNAs and dissecting their role in regulating growth, development, and secondary metabolites production in different organs of a medicinal herb, Picrorhiza kurroa. Planta 2015;241:2551268.

Vashisht D , Nodine M.D. MicroRNA functions in plant embryos. Biochem. Soc. Trans. 2014;42(2):352357.

Ventura L , Don M , Macovei A , Carbonera D , Buttafava A , Mondoni A , Rossi G , Balestrazzi A. Understanding the molecular pathways associated with seed vigor. Plant Physiol. Biochem. 2012;60:196206.

Voinnet O. Origin, biogenesis, and activity of plant microRNAs. Cell 2009;136:669687.

Wagner GJ , Kroumova A.B. The use of RNAi to elucidate and manipulate secondary metabolite synthesis in plants. In: Ying SY (ed.). Current Perspectives in microRNAs (miRNA). Dordrecht, Netherlands: Springer, 2008; pp. 431459.

Wang CY , Zhang S , Yu Y , Luo YC , Liu Q , Ju C , Zhang YC , Qu LH , Lucas WJ , Wang X , Chen Y.Q. MiR397b regulates both lignin content and seed number in Arabidopsis via modulating a laccase involved in lignin biosynthesis. Plant Biotechnol. J. 2014;12:11321142.

Wang L , Liu H , Li D , Chen H. Identification and characterization of maize microRNAs involved in the very early stage of seed germination. BMC Genomics 2011;12:154.

Wang L , Zhao JG , Zhang M , Li WX , Luo KG , Lu ZG , Zhang CQ , Jin B. Identification and characterization of microRNA expression in Ginkgo biloba L. leaves. Tree Genet. Genomes 2015;11:76.

Wang YG , An M , Zhou SF , She YH , Li WC , Fu F.L. Expression profile of maize microRNAs corresponding to their target genes under drought stress. Biochem. Genet. 2014;52:474493.

Wang Y , Wang Y , Song Z , Zhang H. Repression of MYBL2 by both microRNA858a and HY5 leads to the activation of anthocyanin biosynthetic pathway in Arabidopsis. Mol. Plant 2016;9:13951405.

Warpeha KM , Upadhyay S , Yeh J , Adamiak J , Hawkins SI , Lapik YR , Anderson MB , Kaufman L.S. The GCR1, GPA1, PRN1, NF-Y signal chain mediates both blue light and abscisic acid responses in Arabidopsis. Plant Physiol. 2007;143:15901600.

Waterworth WM , Drury GE , Bray CM , West C.E. Repairing breaks in the plant genome: the importance of keeping it together. New Phytol. 2011;192(4):805822. doi: 10.1111/j.1469-8137.2011.03926.x.

Waterworth WM , Drury GE , Bray CM , West CE . Repairing breaks in the plant genome: the importance of keeping it together. New Phytol. 2011;192(4):80522. doi: 10.1111/j.1469-8137.2011.03926.x.

Waterworth WM , Masnavi G , Bhardwaj RM , Jiang Q , Bray CM , West C.E. A plant DNA ligase is an important determinant of seed longevity. Plant J. 2010;63:848860.

Willmann MR , Mehalick AJ , Packer RL , Jenik P.D. MicroRNAs regulate the timing of embryo maturation in Arabidopsis. Plant Physiol. 2011;155:18711884.

Winkel-Shirley B. Flavonoid biosynthesis. A colorful model for genetics, biochemistry, cell biology, and biotechnology. Plant Physiol. 2001;126:485493.

Wu J , Wang D , Liu Y , Wang L , Qiao X , Zhang S. Identification of miRNAs involved in pear fruit development and quality. BMC Genomics 2014;15:953.

Wu L , Zhang QQ , Zhou HY , Ni FR , Wu XY , Qi Y.J. Rice microRNA effector complexes and targets. Plant Cell 2009;21:34213435.

Wu L , Zhou H , Zhang Q , Zhang J , Ni F , Liu C , Qi Y. DNA methylation mediated by a microRNA pathway. Mol Cell. 2010;38:465475.

Yang F , Cai J , Yang Y , Liu Z. Overexpression of microRNA828 reduces anthocyanin accumulation in Arabidopsis. PCTOC 2013;115:159167.

Yang J , Zhang N , Mi X , Wu L , Ma R , Zhu X , Yao L , Jin X , Si H , Wang D. Identification of miR159s and their target genes and expression analysis under drought stress in potato. Comput. Biol. Chem. 2014;53:204213.

Yang T , Xue L , An L. Functional diversity of miRNA in plants. Plant Sci. 2007;172:423432.

Zhang J , Zhang S , Han S , Li X , Tong Z , Qi L. Deciphering small noncoding RNAs during the transition from dormant embryo to germinated embryo in larches (Larix leptolepis). PLoS ONE 2013;8:e81452.

Zhang S , Yue Y , Sheng L , Wu Y , Fan G , Li A , Hu X , Shangguan M , Wei C. PASmiR: A literature-curated database for miRNA molecular regulation in plant response to abiotic stress. BMC Plant Biol. 2013;13:33.

Zhao M , Tai H , Sun S , Zhang F , Xu Y , Li W.X. Cloning and characterization of maize miRNAs involved in responses to nitrogen deficiency. PLoS ONE 2012;7:e29669.

Zhao N , Ferrer JL , Ross J , Guan J , Yang Y , Pichersky E , Noel JP , F. Chen Structural biochemical, and phylogenetic analyses suggest that indole-3-acetic acid methyltransferase is an evolutionarily ancient member of the SABATH family. Plant Physiol. 2008;146:455467.

Zhao Q , Dixon R.A. Altering the cell wall and its impact on plant disease: From forage to bioenergy. Ann. Rev. Phytopathol. 2014;52:6991.

Zhou L , Liu Y , Liu Z , Kong D , Duan M , Luo L. Genome wide identification and analysis of drought-responsive microRNAs in Oryza sativa. J. Exp. Bot. 2010;61:41574168.

Zhuang Y , Zhou XH , Liu J. Conserved miRNAs and their response to salt stress in wild eggplant Solanum linnaeanum roots. Int. J. Mol. Sci. 2014;15:839849.

Zwenger S , Basu C. Plant terpenoids: Applications and future potentials. Biotechnol. Mol. Biol. Rev. 2008;3:17.

Current Understanding of Regulation of GBF3 Under Abiotic and Biotic Stresses and Its Potential Role in Combined Stress Tolerance

Ahmad A , Niwa Y , Goto S , Ogawa T , Shimizu M , Suzuki A , Kobayashi K , Kobayashi H. bHLH106 integrates functions of multiple genes through their G-Box to confer salt tolerance on Arabidopsis. PloS One. 2015;10:e0126872.

Alber T. Structure of the leucine zipper. Curr. Opin. Genet. Dev. 1992;2:205210.

Bhaskara GB , Yang TH , Verslues P.E. Dynamic proline metabolism: Importance and regulation in water limited environments. Front. Plant Sci. 2015;6:484.

Boratyn GM , Camacho C , Cooper PS , Coulouris G , Fong A , Ma N , Madden TL , Matten WT , McGinnis SD , Merezhuk Y , Raytselis Y , Sayers EW , Tao T , Ye J , Zaretskaya I. BLAST: a more efficient report with usability improvements. Nucleic Acids Res. 2013;41:W29W33.

Cecchini NM , Monteoliva MI , Alvarez M.E. Proline dehydrogenase contributes to pathogen defense in Arabidopsis. Plant Physiol. 2011;155:19471959.

Chen W , Provart NJ , Glazebrook J , Katagiri F , Chang HS , Eulgem T , Mauch F , Luan S , Zou G , Whitham SA , Budworth P.R. Expression profile matrix of Arabidopsis transcription factor genes suggests their putative functions in response to environmental stresses. Plant Cell 2002;14:559574.

Choi HI , Hong JH , Ha JO , Kang JY , Kim S.Y. ABFs, a family of ABA-responsive element binding factors. J. Biol. Chem. 2000;275:17231730.

Chow CN , Zheng HQ , Wu NY , Chien CH , Huang HD , Lee TY , Chiang-Hsieh YF , Hou PF , Yang TY , Chang W.C. PlantPAN 2.0: an update of plant promoter analysis navigator for reconstructing transcriptional regulatory networks in plants. Nucleic Acids Res. 2015:gkv1035v1gkv1035.

Corpet F. Multiple sequence alignment with hierarchical clustering. Nucleic Acids Res. 1988;16:1088110890.

Fabro G , Rizzi YS , Alvarez M.E. Arabidopsis proline dehydrogenase contributes to flagellin mediated PAMP-triggered immunity by affecting RBOHD. Mol. Plant Microbe Interac t. 2016;29:620628.

Fujita Y , Fujita M , Satoh R , Maruyama K , Parvez MM , Seki M , Hiratsu K , Ohme-Takagi M , Shinozaki K , Yamaguchi-Shinozaki K . AREB1 is a transcription activator of novel ABRE-dependent ABA signaling that enhances drought stress tolerance in Arabidopsis. Plant Cell 2005;17:34703488.

Hossain MA , Lee Y , Cho JI , Ahn CH , Lee SK , Jeon JS , Kang H , Lee CH , An G , Park P.B. The bZIP transcription factor OsABF1 is an ABA responsive element binding factor that enhances abiotic stress signaling in rice. Plant Mol. Biol. 2010;72:557566.

Huala E , Dickerman AW , Garcia-Hernandez M , Weems D , Reiser L , LaFond F , Hanley D , Kiphart D , Zhuang J , Huang W , Mueller L , Bhattacharyya D , Bhaya D , Sobral B , Beavis B , Somerville C , Rhee S. The Arabidopsis Information Resource (TAIR): a comprehensive database and web-based information retrieval, analysis, and visualization system for a model plant. Nucleic Acids Res. 2001;29:102105.

Jakoby M , Weisshaar B , Drge-Laser W , Vicente-Carbajosa J , Tiedemann J , Kroj T , Parcy F. bZIP transcription factors in Arabidopsis. Trends Plant Sci. 2002;7:106111.

Kant P , Gordon M , Kant S , Zolla G , Davydov O , Heimer YM , ChalifaCaspi VE , Shaked R , Barak S. Functionalgenomicsbased identification of genes that regulate Arabidopsis responses to multiple abiotic stresses. Plant Cell Environ. 2008;31:697714.

Klimczak LJ , Collinge MA , Farini D , Giuliano G , Walker JC , Cashmore A.R. Reconstitution of Arabidopsis casein kinase II from recombinant subunits and phosphorylation of transcription factor GBF1. Plant Cell 1995;7:105115.

Klimczak LJ , Schindler U , Cashmore A.R. DNA binding activity of the Arabidopsis G-box binding factor GBF1 is stimulated by phosphorylation by casein kinase II from broccoli. Plant Cell 1992;4:8798.

Kumar S , Stecher G , Tamura K. MEGA7: Molecular Evolutionary Genetics Analysis Version 7.0 for Bigger Datasets. Mol Biol Evol. 2016;33:18701874.

Lescot M , Dehais P , Thijs G , Marchal K , Moreau Y , Van de Peer Y , Rouze P , Rombauts S. PlantCARE , a database of plant cisacting regulatory elements and a portal to tools for in silico analysis of promoter sequences. Nucleic Acids Res. 2002;30:325327.

Lu G , Paul AL , McCarty DR , Ferl R.J. Transcription factor veracity: Is GBF3 responsible for ABA-regulated expression of Arabidopsis Adh?. Plant Cell 1996;8:847857.

Menkens AE , Cashmore A.R. Isolation and characterization of a fourth Arabidopsisthaliana G-box-binding factor, which has similarities to Fos oncoprotein. Proc. Natl. Acad. Sci. USA 1994;91:25222526.

Menkens AE , Schindler U , Cashmore A.R. The G-box: A ubiquitous regulatory DNA element in plants bound by the GBF family of bZIP proteins. Trends Biochem. Sci. 1995;20:506510.

272 Pabo CO , Sauer R.T. Transcription factors: Structural families and principles of DNA recognition. Annu. Rev. Biochem. 1992;61:10531095.

Prasch CM , Sonnewald U. Simultaneous application of heat, drought, and virus to Arabidopsis plants reveals significant shifts in signaling networks. Plant Physiol. 2013;162:18491866.

Riechmann JL , Heard J , Martin G , Reuber L , Jiang CZ , Keddie J , Adam L , Pineda O , Ratcliffe OJ , Samaha RR , Creelman R. Arabidopsis transcription factors: Genome-wide comparative analysis among eukaryotes. Science 2000;290:21052110.

Rook F , Gerrits N , Kortstee A , Van Kampen M , Borrias M , Weisbeek P , Smeekens S. Sucrosespecific signalling represses translation of the Arabidopsis ATB2 bZIP transcription factor gene. Plant J. 1998a;15:253263.

Rook F , Weisbeek P , Smeekens S. The light-regulated Arabidopsis bZIP transcription factor gene ATB2 encodes a protein with an unusually long leucine zipper domain. Plant Mol Biol. 1998b;37:171178.

Satoh R , Fujita Y , Nakashima K , Shinozaki K , Yamaguchi-Shinozaki K. A novel subgroup of bZIP proteins functions as transcriptional activators in hypoosmolarity-responsive expression of the ProDH gene in Arabidopsis. Plant Cell Physiol. 2004;45:309317.

Schimid M , Davison TS , Henz SR , Pape UJ , Demar M , Vingron M , Scholkopf B , Weigel D , Lohmann J.U. A gene expression map of Arabidopsis thaliana development. Nat Genet. 2005;37:501506.

Schindler U , Menkens AE , Beckmann H , Ecker JR , Cashmore A.R. Heterodimerization between light-regulated and ubiquitously expressed Arabidopsis GBF bZIP proteins. EMBO J. 1992;11:12611273.

Siberil Y , Doireau P , Gantet P. Plant bZIP Gbox binding factors. Eur. J. Biochem. 2001;268:56555666.

Smykowski A , Zimmermann P , Zentgraf U. G-Box binding factor1 reduces CATALASE2 expression and regulates the onset of leaf senescence in Arabidopsis. Plant Physiol. 2010;153:13211331.

Szklarczyk D , Franceschini A , Wyder S , Forslund K , Heller D , Huerta-Cepas J , Simonovic M , Roth A , Santos A , Tsafou KP , Kuhn M , Bork P , Jensen LJ , Mering C.V. STRING v10: protein -protein interaction networks, integrated over the tree of life. Nucleic Acids Res. 2015;43:D447D452.

Tamai H , Iwabuchi M , Meshi T. Arabidopsis GARP transcriptional activators interact with the Pro-rich activation domain shared by G-box-binding bZIP factors. Plant Cell Physiol. 2002;43:99107.

Terzaghi WB , Bertekap RL , Cashmore A.R. Intracellular localization of GBF proteins and blue lightinduced import of GBF2 fusion proteins into the nucleus of cultured Arabidopsis and soybean cells. Plant J. 1997;11:967982.

ThibaudNissen F , Wu H , Richmond T , Redman JC , Johnson C , Green R , Arias J , Town C.D. Development of Arabidopsis whole genome microarrays and their application to the discovery of binding sites for the TGA2 transcription factor in salicylic acidtreated plants. Plant J. 2006; 47:152162.

Uno Y , Furihata T , Abe H , Yoshida R , Shinozaki K , Yamaguchi-Shinozaki K. Arabidopsis basic leucine zipper transcription factors involved in an abscisic acid-dependent signal transduction pathway under drought and high-salinity conditions. Proc. Natl. Acad. Sci. USA 2000;97:1163211637.

Williams ME , Foster R , Chua N.H. Sequences flanking the hexameric G-box core CACGTG affect the specificity of protein binding. Plant Cell 1992;4:485496.

Xin Z , Mandaokar A , Chen J , Last RL , Browse J. Arabidopsis ESK1 encodes a novel regulator of freezing tolerance. Plant J. 2007;49(5):786799.

Xu P , Chen F , Mannas JP , Feldman T , Sumner LW , Roossinck M.J. Virus infection improves drought tolerance. New Phytol. 2008;180:911 921.

Zdobnov EM , Apweiler R. InterProScanan integration platform for the signature-recognition methods in InterPro. Bioinformatics. 2001;17:847848.

Zhou JM , Trifa Y , Silva H , Pontier D , Lam E , Shah J , Klessig D.F. NPR1 differentially interacts with members of the TGA/OBF family of transcription factors that bind an element of the PR1 gene required for induction by salicylic acid. Mol. Plant Microbe Interact. 2000;13:191202.

Zimmermann P , Hirsch-Hoffmann M , Hennig L , Gruissem W. GENEVESTIGATOR. Arabidopsis microarray database and analysis toolbox. Plant Physiol. 2004;136:26212632.

microRNAs: Key Modulators of Drought Stress Responses in Plants

Abe H , Urao T , Ito T , Seki M , Shinozaki K , Yamaguchi-Shinozaki K. Arabidopsis AtMYC2 (bHLH) and AtMYB2 (MYB) function as transcriptional activators in abscisic acid signaling. Plant Cell 2003; 15: 6378.

An J , Lai J , Sajjanhar A , Lehman, ML , Nelson C.C. miRPlant: An integrated tool for identification of plant miRNA from RNA sequencing data. BMC Bioinf. 2014; 15: 275. doi:10.1186/1471-2105-15-275.

Arenas-Huertero C , Perez B , Rabanal F , Blanco-Melo D , De la Rosa C , Estrada-Navarrete G , Sanchez F , Covarrubias AA , Reyes J.L. Conserved and novel miRNAs in the legume Phaseolus vulgaris in response to stress. Plant Mol. Biol. 2009; 70: 385401.

Axtell MJ , Bartel D.P. Antiquity of microRNAs and their targets in land plants. Plant Cell 2005; 17: 16581673.

Bakhshi B , Fard EM , Nikpay N , Ebrahimi MA , Bihamta MR , Mardi M , Salekdeh G.H. MicroRNA signatures of drought signaling in rice root. PLoS ONE 2016; 11(6): e0156814. doi:10.1371/journal.pone.0156814.

Baras AS , Mitchell CJ , Myers JR , Gupta S , Weng LC , Ashton JM , Cornish TC , Pandey A , Halushka M.K. miRgeA multiplexed method of processing small RNA-seq data to determine microRNA entropy. PLoS ONE 2015; 10: e0143066. doi:10.1371/journal.pone.0143066.

Barrera-Figueroa BE , Gao L , Diop NN , Wu Z , Ehlers JD , Roberts PA , Close TJ , Zhu JK , Liu R. Identification and comparative analysis of drought-associated microRNAs in two cowpea genotypes. BMC Plant Biol. 2011; 11(1): 127.

Bartel D . MicroRNAs: Genomics, biogenesis, mechanism, and function. Cell 2004; 116: 281297.

Bertolini E , Verelstb W , Hornerd DS , Gianfranceschid L , Piccolod V , Inzb D , Pa ME , Micaa E. Addressing the role of microRNAs in reprogramming leaf growth during drought stress in Brachypodium distachyon. Mol. Plant 2013; 6(2): 423443.

Bonnet E , He Y , Billiau K , Van de Peer Y . TAPIR, a web server for the prediction of plant micro RNA targets, including target mimics. Bioinformatics 2010; 26: 15661568. doi:10.1093/bioinformatics/btq233.

Boualem A , Laporte P , Jovanovic M , Laffont C , Plet J , Combier JP , Niebel A , Crespi M , Frugier F. MicroRNA166 controls root and nodule development in Medicagotruncatula. Plant J. 2008; 54: 876887. doi:10.1111/j.1365-313X.2008.03448.x.

282 Chae H , Rhee S , Nephew KP , Kim S. BioVLAB-MMIA-NGS: microRNA-mRNA integrated analysis using high throughput sequencing data. Bioinformatics 2015; 31: 265267. doi:10.1093/bioinformatics/btu614.

Chiang K , Shu J , Zempleni J , Cui J. Dietary microRNA database (DMD): An archive database and analytic tool for food-borne microRNAs. PLoS ONE 2015; 10: e0128089. doi:10.1371/journal.pone.0128089.

Couzigou JM , Lauressergues D , Bcard G , Combier J.P. miRNA-encoded peptides (miPEPs): A new tool to analyze the roles of miRNAs in plant biology. RNA Biol. 2015; 12: 11781180. doi:10.1080/15476286.2015.10 94601.

Covarrubias AA , Reyes J.L. Post-transcriptional gene regulation of salinity and drought responses by plant microRNAs. Plant Cell Environ. 2010; 33(4): 481489.

Cruz C.M.H. Drought stress and reactive oxygen species: Production, scavenging and signaling. Plant Signal. Behav. 2008; 3: 156165.

Dezulian T , Remmert M , Palatnik JF , Weigel D , Huson D.H. Identification of plant microRNA homologs. Bioinformatics 2006; 22(3): 359360.

Ding Y , Tao Y , Zhu C. Emerging roles of microRNAs in the mediation of drought stress response in plants. J. Exp. Bot. 2013; 64: 30773086.

Eldem V , Akcay UC , Ozhuner E , Bakir Y , Uranbey S , Unver T. Genome-wide identification of miRNAs responsive to drought in peach (Prunus persica) by high-throughput deep sequencing. PLoS ONE 2012; 7: e50298.

Evers M , Huttner M , Dueck A , Meister G , Engelmann J.C. miRA: Adaptable novel miRNA identification in plants using small RNA sequencing data. BMC Bioinf. 2015; 16: 370. doi:10.1186/s12859-015-0798-3.

Fahlgren N , Hill ST , Carrington JC , Carbonell A . P-SAMS: A web site for plant artificial microRNA and synthetic trans-acting small interfering RNA design. Bioinformatics 2016; 32: 157158. doi:10.1093/bioinformatics/btv534.

Fan S , Blake TJ , Blumwald E. The relative contribution of elastic and osmotic adjustments to turgor maintenance of woody species. Physiol. Plant. 1994; 90(2): 408413.

Ferdous J , Carlos J , Sanchez-Ferrero JC , Langridge P , Milne L , Chowdhury J , Brien C , Tricker P.J. Differential expression of microRNAs and potential targets under drought stress in barley. Plant Cell Environ. 2017; 40: 1124.

Ferdous J , Hussain SS , Shi B.J. Role of microRNAs in plant drought tolerance. Plant Biotechnol. J. 2015; 13(3): 293305.

Frazier TP , Sun G , Burklew CE , Zhang B.H. Salt and drought stresses induce the aberrant expression of microRNA genes in tobacco. Mol. Biotechnol. 2011; 49: 159165.

Fridovich I. Superoxide radical and superoxide dismutases. Annu. Rev. Biochem. 1995; 64: 97112.

Galli V , Guzman F , de Oliveira Lfv , Loss-Morais G , Krbes AP , Silva SD , Margis-Pinheiro MM , Margis R. Identifying microRNAs and transcript targets in Jatropha seeds. PLoS ONE 2014; 9(2): e83727. doi:10.1371/journal.pone.0083727.

Gao F , Wang N , Li H , Liu J , Fu C , Xiao Z , Wei C , Lu X , Feng J , Zhou Y. Identification of drought responsive microRNAs and their targets in Ammopiptanthus mongolicus by using highthroughput sequencing. Sci. Rep. 2016; 6: 34601.

Gill SS , Tuteja N. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol. Biochem. 2010; 48: 909930.

Guan Q , Lu X , Zeng H , Zhang Y , Zhu J. Heat stress induction of miR398 triggers a regulatory loop that is critical for thermotolerance in Arabidopsis. Plant J. 2013; 74(5): 840851.

Guilfoyle TJ , Hagen G. Auxin response factors. Curr. Opin. Plant Biol. 2007; 10: 453460. doi:10.1016/j.pbi.2007.08.014.

Guo HS , Xie Q , Fei JF , Chua N.H. MicroRNA directs mRNA cleavage of the transcription factor NAC1 to downregulate auxin signals for arabidopsis lateral root development. Plant Cell 2005; 17: 13761386.

Hackenberg M , Rodrguez-Ezpeleta N , Aransay A.M. miRanalyzer: An update on the detection and analysis of microRNAs in high-throughput sequencing experiments. Nucl. Acids Res. 2011; 39: W132W138. doi:10.1093/nar/gkr247.

Hanin M , Brini F , Ebel C , Masmoudi K. Plant dehydrins and stress tolerance. Plant Signal. Behav. 2011; 6: 10, 17.

Hasson A , Plessis A , Blein T , Adroher B , Grigg S , Tsiantis M , Boudaoud A , Damerval C , Laufs P. Evolution and diverse roles of the CUP-SHAPED COTYLEDON genes in Arabidopsis leaf development. Plant Cell 2011; 23: 5468.

Hsiao TC , Xu L.K. Sensitivity of growth of roots versus leaves to water stress: Biophysical analysis and relation to water transport. J. Exp. Bot. 2000; 51: 15961616.

Hsu SD , Lin FM , Wu WY , Liang C , Huang WC , Chan WL , Tsai WT , et al. miRTarBase: A database curates experimentally validated microRNA-target interactions. Nucl. Acids Res. 2011; 39: D163D169. doi:10.1093/nar/gkq1107.

Huang TH , Fan B , Rothschild MF , Hu ZL , Li K , Zhao S.H. MiRFinder: An improved approach and software implementation for genome-wide fast microRNA precursor scans. BMC Bioinf. 2007; 8: 341.

Jones-Rhoades MW , Bartel D.P. Computational identification of plant microRNAs and their targets, including a stress-induced miRNA. Mol. Cell 2004; 14: 787799.

Jones-Rhoades MW , Bartel DP , Bartel B. MicroRNAs and their regulatory roles in plants. Annu. Rev. Plant Biol. 2006; 57: 1953.

Kantar M , Lucas SJ , Budak H. miRNA expression patterns of Triticum dicoccoides in response to shock drough t stress. Planta 2011; 233: 471484.

Kantar M , Unver T , Budak H. Regulation of barley miRNAs upon dehydration stress correlated with target gene expression. Funct. Integr. Genom. 2010; 10: 493507.

Katiyar A , Smita S , Muthusamy SK , Chinnusamy V , Pandey DM , Bansal K.C. Identification of novel drought-responsive microRNAs and trans-acting siRNAs from Sorghum bicolor(L.) Moench by high-throughput sequencing analysis. Front. Plant Sci. 2015; 6: 506. doi:10.3389/fpls.2015.00506.

Khraiwesh B , Zhu JK , Zhu J.H. Role of miRNAs and siRNAs in biotic and abiotic stress responses of plants. Biochim. Biophys. Acta 2012; 1819: 137148.

Kozomara A , Griths-Jones S. miRBase: Annotating high confidence microRNAs using deep sequencing data. Nucl. Acids Res. 2014; 42: D68D73. doi:10.1093/nar/gkt1181.

Kramer PJ , Boyer J.S. Water Relations of Plants and Soils. 1st edition, Academic Press, London, 1995.

Kulcheski FR , de Oliveira LF , Molina LG , Almero MP , Rodrigues FA , Marcolino J , Barbosa JF , et al. Identification of novel soybean microRNAs involved in abiotic and biotic stresses. BMC Genom. 2011; 12: 307.

283 Kumar R. Role of microRNAs in biotic and abiotic stress responses in crop plants. Appl. Biochem. Biotechnol. 2014; 174(1): 1193.

Kumimoto RW , Adam L , Hymus GJ , Repetti PP , Reuber TL , Marion CM , Hempel FD , Ratcliffe O.J. The nuclear factor Y subunits NF-YB2 and NF-YB3 play additive roles in the promotion of flowering by inductive long-day photoperiods in Arabidopsis. Planta 2008; 228: 709723.

Kurihara Y , Watanabe Y. Arabidopsis micro-RNA biogenesis through Dicer-like 1 protein functions. Proc. Natl. Acad. Sci. USA 2004; 101(34): 1275312758.

Lee R , Feinbaum R , Ambros V. The C. Elegans heterochronic gene lin-4 encodes small RNAs with antisense complementarity to lin-14. Cell 1993; 75(5): 843854.

Lee Y , Ahn C , Han J , Choi H , Kim J , Yim J , Lee J , Provost P , Radmark O , Kim S , Kim V.N. The nuclear RNase III Drosha initiates microRNA processing. Nature 2003; 425(6956): 415419.

Li Y , Wan L , Bi S , Wan Z , Li Z , Cao J , Tong Z , Xu H , He F , Li X. Identification of drought responsive microRNAs from roots and leaves of Alfalfa by High-Throughput sequencing. Genes 2017; 8: 119.

Liu HH , Tian X , Li YJ , Wu CA , Zheng C.C. Microarray-based analysis of stress-regulated microRNAs in Arabidopsis thaliana. RNA 2008; 14(5): 836 836.

Liu PP , Montgomery TA , Fahlgren N , Kasschau K.D. , Nonogaki H , Carrington J.C. Repression of AUXIN RESPONSE FACTOR10 by microRNA160 is critical for seed germination and post-germination stages. Plant J. 2007; 52: 133146.

Liu Q , Zhang YC , Wang CY , Luo YC , Huang QJ , Chen SY , Zhou H , Qu LH , Chen Y.Q. Expression analysis of phytohormone regulated microRNAs in rice, implying their regulation roles in plant hormone signaling. FEBS Lett. 2009; 583: 723728.

JC Lima , G Loss-Morais , R Margis . MicroRNAs play critical roles during plant development and in response to abiotic stresses. Genet. Mol. Biol. 2012; 35(4) (suppl): 10691077.

Llave C , Xie Z , Kasschau KD , Carrington J.C. Cleavage of Scarecrow-like mRNA targets directed by a class of Arabidopsis miRNA. Science 2002; 297: 20532056.

Lorenzetti APR , de Antonio GYA , Paschoal AR , Domingues DS . PlanTE-MIR DB: A database for transposable element-related microRNAs in plant genomes. Funct. Integr. Genom. 2016; 16: 235242. doi:10.1007/s10142-016-0480-5.

Lu S , Sun YH , Shi R , Clark C , Li L , Chiang VL . Novel and mechanical stress-responsive MicroRNAs in Populus trichocarpa that are absent from Arabidopsis. Plant Cell 2005; 17: 21862203.

Mallory AC , Vaucheret H. Functions of microRNAs and related small RNAs in plants. Nat. Genet. 2006; 38: S31S36. doi:101038/ng1791.

Martin-Trillo M , Cubas P. TCP genes: A family snapshot ten years later. Trends Plant Sci. 2010; 15: 3139.

Martinez-Sanchez A , Murphy C.L. MicroRNA target identification experimental approaches. Biology 2013; 2: 189205.

Meng J , Shi GL , Luan Y.S. Plant miRNA function prediction based on functional similarity network and transductive multi-label classification algorithm. Neuro Comput. 2016; 179: 283289. doi:10.1016/j.neucom.2015.12.011.

Meng Y , Gou L , Chen D , Mao C , Jin Y , Wu P , et al. PmiRKB: a plant microRNA knowledge base. Nucleic Acids Res. 2011; 39: D181 D187. doi:10.1093/nar/gkq721

Mittler R. Oxidative stress, antioxidants and stress tolerance. Trends Plant Sci. 2002; 7: 405410.

Muljo SA , Kanellopoulou C , Aravind L . MicroRNA targeting in mammalian Genomes: Genes and mechanisms. Wiley Interdiscip. Rev. Syst. Biol. Med. 2010; 2(2): 148161.

Muoz-Mrida A, Perkins JR , Viguera E , Thode G , Bejarano ER , Prez-Pulido A.J. Semirna: Searching for plant miRNAs using target sequences. Omics 2012; 16: 168177. doi:10.1089/omi.2011.0115.

Nanjo T , Fujita M , Seki M. , Kato T , Tabata S , Shinozaki K. Toxicity of free proline revealed in an Arabidopsis T-DNA-tagged mutant deficient in proline dehydrogenase. Plant Cell Physiol. 2003; 44: 541548.

Nanjo T , Kobayashi M , Yoshiba Y , Sanada Y , Wada K , Tsukaya H , Kakubari Y , Yamaguchi-Shinozaki K , Shinozaki K . Biological functions of proline in morphogenesis and osmotolerance revealed in antisense transgenic Arabidopsis thaliana. Plant J. 1999; 18: 185193.

Neumann P.M. Coping mechanisms for crop plants in drought-prone environments. Ann. Bot. 2008; 101(7): 901907.

Numnark S , Mhuantong W , Ingsriswang S , Wichadakul D. C-mii: A tool for plant miRNA and target identification. BMC Genom. 2012; 13: S16. doi:10.1186/1471-2164-13-S7-S16.

Park W , Li J , Song R , Messing J , Chen X. CARPEL FACTORY, a Dicer homolog, and HEN1, a novel protein, act in microRNA metabolism in Arabidopsis thaliana. Curr. Biol. 2002; 12: 14841495.

Pashkovskiy PP , Ryazansky S.S. Biogenesis, evolution, and functions of plant microRNAs. Biochemistry 2013; 78(6): 627637.

Patel P , Ramachandruni SD , Kakrana A , Nakano M , Meyers B.C. miTRATA: A web-based tool for microRNA truncation and tailing analysis. Bioinformatics 2016; 32: 450452. doi:10.1093/bioinformatics/btv583.

Reddy AR , Chaitanya KV , Vivekanandan M. Drought induced responses of photosynthesis and antioxidant metabolism in higher plants. J. Plant Physiol. 2004; 161: 11891202.

Remita MA , Lord E , Agharbaoui Z , Leclercq M , Badawi M , Makarenkov V , Sarhan F , Diallo A.B. WMP: A novel comprehensive wheat miRNA database, including related bioinformatics software. BioRxiv. 2015; 024893. doi:10.1101/024893.

Reyes JL , Chua N.H. ABA induction of miR159 controls transcript levels of two MYB factors during Arabidopsis seed germination. Plant J. 2007; 49: 592606.

Rhee S , Chae H , Kim S. PlantMirnaT: miRNA and mRNA integrated analysis fully utilizing characteristics of plant sequencing data. Methods 2015; 83: 8087. doi:10.1016/j.ymeth.2015.04.003.

Rodriguez RE , Mecchia MA , Debernardi JM , Schommer C , Weigel D , Palatnik J.F. Control of cell proliferation in Arabidopsis thaliana bymicroRNA miR396. Development 2010; 137: 103112.

Rueda A , Barturen G , Lebrn R , Gmez-Martn C , Alganza , Oliver JL , Hackenberg M. sRNAtoolbox: An integrated collection of small RNA research tools. Nucl. Acids Res. 2015; 43: W467W473. doi:10.1093/nar/gkv555.

Regger S , Grobhans H. MicroRNA turnover: When, how, and why. Trends Biochem. Sci. 2012; 37(10): 436446.
Shinozaki K , Yamaguchi-Shinozaki K. Gene networks involved in drought stress response and tolerance. J. Exp. Bot. 2006; 58(2): 221227.
284 Shriram V , Kumar V , Devarumath RM , Khare TS , Wani S.H. MicroRNAs as potential targets for abiotic stress tolerance in plants. Front. Plant Sci. 2016; 7: 817. doi:10.3389/fpls.2016.00817.
Shuai P , Liang D , Zhang Z , Yin W , Xia X. Identification of drought-responsive and novel Populus trichocarpa microRNAs by high-throughput sequencing and their targets using degradome analysis. BMC Genom. 2013; 14: 233.
Sun G. MicroRNAs and their diverse functions in plants. Plant Mol. Biol. 2012; 80: 1736. doi:10.1007/s11103-011-9817-6.
Sunkar R , Kapoor A , Zhu J.K. Posttranscriptional induction of two Cu/Zn superoxide dismutase genes in Arabidopsis is mediated by down-regulation of miR398 and important for oxidative stress tolerance. Plant Cell 2006; 18: 20512065.
Sunkar R , Zhu J.K. Novel and stress-regulated microRNAs and other small RNAs from Arabidopsis. Plant Cell 2004; 16: 20012019.
Trindade I , Capitao C , Dalmay T , Fevereiro MP , Santos D.M. miR398 and miR408 are upregulated in response to water deficit in Medicagotruncatula. Planta 2010; 231: 705716.
Vaucheret H , Vazquez F , Crete P , Bartel D.P. The action of ARGONAUTE1 in the miRNA pathway and its regulation by the miRNA pathway are crucial for plant development. Genes Dev. 2004; 18: 11871197.
Voinnet O. Origin, biogenesis, and activity of plant microRNAs. Cell 2009; 136: 669687.
Wang JW , Wang LJ , Mao YB , Cai WJ , Xue HW , Chen X.Y. Control of root cap formation by microRNA-targeted auxin response factors in Arabidopsis. Plant Cell 2005; 17: 22042216.
Wang T , Chen L , Zhao M , Tian Q , Zhang W.H. Identification of drought-responsive microRNAs in Medicago truncatula by genome-wide high throughput sequencing. BMC Genom. 2011; 12: 367.
Wei L , Zhang D , Xiang F , Zhang Z. Differentially expressed miRNAs potentially involved in the regulation of defense mechanism to drought stress in maize seedlings. Int. J. Plant Sci. 2009; 170: 979989.
Xue C , Li F , He T , G P Liu , Li Y , Zhang X. Classification of real and pseudo microRNA precursors using local structure-sequence features and support vector machine. BMC Bioinf. 2005; 6: 310.
Yang F , Yu D. Overexpression of Arabidopsis miR396 enhances drought tolerance in transgenic tobacco plants. Acta Bot. Yunnan. 2009; 31: 421426.
Yang X , Li L. miRDeep-P: A computational tool for analyzing the microRNA transcriptome in plants. Bioinformatics 2011; 27: 26142615. doi:10.1093/bioinformatics/btr430.
Yi X , Zhang Z , Ling Y , Xu W , Su Z. PNRD: A plant non-coding RNA database. Nucl. Acids Res. 2015; 43: D982D989. doi:10.1093/nar/gku1162.
Yoon EK , Yang JH , Lim J , Kim SH , Kim SK , Lee W.S. Auxin regulation of the microRNA390-dependent transacting small interfering RNA pathway in Arabidopsis lateral root development. Nucl. Acids Res. 2010; 38: 13821391.
Zhang B. MicroRNA: a new target for improving plant tolerance to abiotic stress. J. Exp. Bot. 2015; 66: 17491761. doi:10.1093/jxb/erv013.
Zhang B , Pan X , Cannon CH , Cobb GP , Anderson T.A. Conservation and divergence of plant microRNA genes. Plant J. 2006; 46: 243259.
Zhang S , Yue Y , Sheng L , Wu Y , Fan G , Li A , Hu X , ShangGuan M , Wei C. PASmiR: A literature-curated database form iRNA molecular regulation in plant response to abiotic stress. BMC Plant Biol. 2013; 13: 33. doi:10.1186/1471-2229-13-33.
Zhang X , Zou Z , Gong P , Zhang J , Ziaf K , Li H , Xiao F , Ye Z. Over-expression of microRNA169 confers enhanced drought tolerance to tomato. Biotechnol. Lett. 2011; 33: 403409.
Zhang Z , Jiang L , Wang J , Chen M. MTide: An integrated tool for the identification of miRNA-target interaction in plants. Bioinformatics 2014; 31: 290291. doi:10.1093/bioinformatics/btu633.
Zhang Z , Yu J , Li D , Zhang Z , Liu F , Zhou X , Wang T , Ling Y , Su Z. Pmrd: Plant microRNA database. Nucl. Acids Res. 2010; 38: D806D813. doi:10.1093/nar/gkp818.
Zhao B , Liang R , Ge L , Li W , Xiao H , Lin H , Ruan K , Jin Y. Identification of drought-induced microRNAs in rice. Biochem. Biophys. Res. Commun. 2007; 354: 585590.
Zhou LG , Liu YH , Liu ZC , Kong DY , Duan M , Luo LJ. Genome-wide identification and analysis of drought-responsive microRNAs in Oryza sativa. J. Exp. Bot. 2010; 61: 41574168.

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Agarwal P , Agarwal PK , Joshi AJ , Sopory SK , Reddy M.K. Overexpression of PgDREB2A transcription factor enhances abiotic stress tolerance and activates downstream stress-responsive genes. Mol. Biol. Rep. 2010; 37(2):11251135. doi:10.1007/s11033-009-98858.
Agarwal PK , Agarwal P , Jain P , Jha B , Reddy MK , Sopory S.K. Constitutive overexpression of a stress-inducible small GTP-binding protein PgRab7 from Pennisetum glaucum enhances abiotic stress tolerance in transgenic tobacco. Plant Cell Rep. 2008; 27:105115. doi:10.1007/s00299-007-0446-0.
Aghaei K , Ehsanpour AA , Komatsu S. Proteome analysis of potato under salt stress. J. Proteome Res. 2008; 7(11):48584868. doi:10.1021/pr800460y.
290 Aghaei K , Ehsanpour AA , Shah AH , Komatsu S. Proteome analysis of soybean hypocotyl and root under salt stress. Amino Acids 2009; 36(1):9198. doi:10.1007/s00726-008-0036-7.
Agrawal GK , Jwa NS , Rakwal R. Rice proteomics: Ending phase I and the beginning of phase II. Proteomics 2009; 9:935963. doi:10.1002/pmic.200800594.
Alvarez S , Marsh EL , Schroeder SG , Schachtman D.P. Metabolomic and proteomic changes in the xylem sap of maize under drought. Plant Cell Environ. 2008; 31(3):325340. doi:10.1111/j.1365-3040.2007.01770.x.
Apse MP , Aharon GS , Snedden WA , Blumwald E. Salt tolerance conferred by overexpression of a vacuolar Na+/H+ antiport in Arabidopsis. Science 1999; 285(5431):12561258. doi:10.1126/science.285.5431.1256.
Askari H , Edqvist J , Hajheidari M , Kafi M , Salekdeh G.H. Effects of salinity levels on proteome of Suaeda aegyptiaca leaves. Proteomics 2006; 6(8):25422554. doi:10.1002/pmic.200500328.
Barkla BJ , Vera-Estrella R , Hernandez-Coronado M , Pantoja O. Quantitative proteomics of the tonoplast reveals a role for glycolytic enzymes in salt tolerance. Plant Cell 2009; 21(12):40444058. doi:10.1105/tpc.109.069211.
Bhadra Rao Tsr , Naresh JV , Reddy PS , Reddy MK , Mallikarjuna G. Expression of Pennisetum glaucum Eukaryotic Translational Initiation Factor 4A (PgEIF4a) confers improved drought, salinity, and oxidative stress tolerance in groundnut. Front. Plant Sci. 2017; 8(453):115. doi:10.3389/fpls.2017.00453.
Castro AJ , Carapito C , Zorn N , Magne C , Leize E , Van Dorsselaer A , Clement C. Proteomic analysis of grapevine (Vitis vinifera L.) tissues subjected to herbicide stress. J. Exp. Bot. 2005; 56(421):27832795. doi:10.1093/jxb/eri271.

Chen FG , Zhang S , Jian g H , Ma WJ , Korpelainen H , Li C. Comparative proteomics analysis of salt response reveals sex-related photosynthetic inhibition by salinity in Populus cathayana cuttings. J. Proteome Res. 2011; 10(9):39443958. doi:10.1021/pr200535r.

Cheng T , Chen J , Zhang J , Shi S , Zhou Y , Lu L , Wang P , et al. Physiological and proteomic analyses of leaves from the halophyte Tangut Nitraria reveals diverse response pathways critical for high salinity tolerance. Front. Plant Sci. 2015; 6:30. doi:10.3389/fpls.2015.00030.

Cheng YW , Qi YC , Zhu Q , Chen X , Wang N , Zhao X , Chen HY , Cui XJ , Xu LL , Zhang W. New changes in the plasma membrane-associated proteome of rice roots under salt stress. Proteomics 2009; 9(11):31003114. doi:10.1002/pmic.200800340.

Desai MK , Mishra RN , Verma D , Nair S , Sopory SK , Reddy M.K. Structural and functional analysis of a salt stress inducible gene encoding voltage dependent anion channel (VDAC) from pearl millet (Pennisetum glaucum). Plant Physiol. Biochem. 2006; 44:483493. doi:10.1016/j.plaphy.2006.08.008.

Diedhiou CJ , Popova OV , Golldack D. Transcript profiling of the salt-tolerant Festuca rubra ssp. litoralis reveals a regulatory network controlling salt acclimatization. J. Plant Physiol. 2009; 166(7):697711. doi:10.1016/j.jplph.2008.09.015.

Fatehi F , Hosseinzadeh A , Alizadeh H , Brimavandi T , Struik P.C. The proteome response of salt-resistant and salt-sensitive barley genotypes to long-term salinity stress. Mol. Biol. Rep. 2012; 39(5):63876397. doi:10.1007/s11033-012-1460-z.

Ganguly M , Datta K , Roychoudhury A , Gayen D , Sengupta DN , Datta S.K. Overexpression of Rab16A gene in indica rice variety for generating enhanced salt tolerance. Plant Signal. Behav. 2012; 7(4):502509. doi:10.4161/psb.19646.

Gao F , Zhou Y , Zhu W , Li X , Fan L , Zhang G. Proteomic analysis of cold stress-responsive proteins in Thellungiella rosette leaves. Planta 2009; 230(5):10331046; PMID: 19705148. doi:10.1007/s00425-009-1003-6.

Geissler N , Hussin S , Koyro H.W. Elevated atmospheric CO2 concentration enhances salinity tolerance in Aster tripolium L. Planta 2010; 231(3):583594. doi:10.1007/s00425-009-1064-6.

Ghosh A , Pareek A , Sopory SK , Singla-Pareek S.L. A glutathione responsive rice glyoxalase II, OsGLYII-2, functions in salinity adaptation by maintaining better photosynthesis efficiency and anti-oxidant pool. Plant J. 2014; 80(1):93105. doi:10.1111/tpj.12621.

Gong F , Hu X , Wang W. Proteomic analysis of crop plants under abiotic stress conditions: Where to focus our research? Front. Plant Sci. 2015; 6(418):15. doi:10.3389/fpls.2015.00418.

Gutha LR , Reddy A.R. Rice DREB1B promoter shows distinct stress-specific responses, and the overexpression of cDNA in tobacco confers improved abiotic and biotic stress tolerance. Plant Mol. Biol. 2008; 68(6):533555. doi:10.1007/s11103-008-9391-8.

Haak DC , Fukao T , Grene R , Hua Z , Ivanov R , Perrella G , Li S. Multilevel regulation of abiotic stress responses in plants. Front. Plant Sci. 2017; 8(1564):124. doi:10.3389/fpls.2017.01564.

Hanin M , Ebel C , Ngom M , Laplaze L , Masmoudi K. New insights on plant salt tolerance mechanisms and their potential use for breeding. Front. Plant Sci. 2016; 7:1787. doi:10.3389/fpls.2016.01787.

Hu Y , Wang G , Chen GY , Fu X , Yao S.Q. Proteome analysis of Saccharomyces cerevisiae under metal stress by two-dimensional differential gel electrophoresis. Electrophoresis 2003; 24(9):14581470. doi:10.1002/elps.200390188.

Jacoby RP , Millar AH , Taylor N.L. Wheat mitochondrial proteomes provide new links between antioxidant defense and plant salinity tolerance. J. Proteome Res. 2010; 9(12):65956604. doi:10.1021/pr1007834.

Jami SK , Clark GB , Turlapati SA , Handley C , Roux SJ , Kirti P.B. Ectopic expression of an annexin from Brassica juncea confers tolerance to abiotic and biotic stress treatments in transgenic tobacco. Plant Physiol. Biochem. 2008; 46(12):10191030. doi:10.1016/j.plaphy.2008.07.006.

Jan A , Maruyama K , Todaka D , Kidokoro S , Abo M , Yoshimura E , Shinozaki K , Nakashima K , Yamaguchi-Shinozaki K. OsTZF1, a CCCH-tandem zinc finger protein, confers delayed senescence and stress tolerance in rice by regulating stress-related genes. Plant Physiol. 2013; 161(3):12021216. doi:10.1104/pp.112.205385.

Jha B , Agarwal PK , Reddy PS , Lal S , Sopory SK , Reddy M.K. Identification of salt-induced genes from Salicornia brachiata, an extreme halophyte through expressed sequence tags analysis. Genes Genet. Syst. 2009; 84(2):111120. doi:10.1266/ggs.84.111.

Jia H , Shao M , He Y , Guan R , Chu P , Jiang H. Proteome dynamics and physiological responses to short-term salt stress in Brassica napus leaves. PLoS ONE 2015; 10(12):e0144808. doi:10.1371/journal.pone.0144808.

Jiang Y , Yang B , Harris NS , Deyholos M.K. Comparative proteomic analysis of NaCl stress-responsive proteins in Arabidopsis roots. J. Exp. Bot. 2007; 58(13):35913607. doi:10.1093/jxb/erm207.

Kav NNV , Srivastava S , Goonewardende L , Blade S.F. Proteome-level changes in the roots of Pisum sativum in response to salinity. Ann. Appl. Biol. 2004; 145:217230. doi:10.1111/j.1744-7348.2004.tb00378.x.

291 Kumar R , Mustafiz A , Sahoo KK , Sharma V , Samanta S , Sopory SK , Pareek A , Singla-Pareek S.L. Functional screening of cDNA library from a salt tolerant rice genotype Pokkali identifies mannose-1-phosphate guanyl transferase gene (OsMPG1) as a key member of salinity stress response. Plant Mol. Biol. 2012; 79(6):555568. doi:10.1007/s11103-012-99288.

Li W , Zhang C , Lu Q , Wen X , Lu C. The combined effect of salt stress and heat shock on proteome profiling in Suaeda salsa. J. Plant Physiol. 2011; 168(15):17431752. doi:10.1016/j.jplph.2011.03.018.

Li W , Zhao F , Fang W , Xie D , Hou J , Yang X , Zhao Y , Tang Z , Nie L , Lv S. Identification of early salt stress responsive proteins in seedling roots of upland cotton (Gossypium hirsutum L.) employing iTRAQ-based proteomic technique. Front. Plant Sci. 2015; 6:732. doi:10.3389/fpls.2015.00732.

Liu H , Zhang H , Yang Y , Li G , Yang Y , Wang X , Basnayake BM , Li D , Song F. Functional analysis reveals pleiotropic effects of rice RING-H2 finger protein gene OsBIRF1 on regulation of growth and defense responses against abiotic and biotic stresses. Plant Mol. Biol. 2008; 68(12):1730. doi:10.1007/s11103-008-9349-x.

Long R , Li M , Zhang T , Kang J , Sun Y , Cong L , Gao Y , Liu F , Yang Q. Comparative proteomic analysis reveals differential root proteins in Medicago sativa and Medicago truncatula in response to salt stress. Front. Plant Sci. 2016; 7:424. doi:10.3389/fpls.2016.00424.

Mahajan S , Sopory SK , Tuteja N. Cloning and characterization of CBL-CIPK signalling components from a legume (Pisum sativum). FEBS J. 2006; 273(5):907925. doi:10.1111/j.1742-4658.2006.05111.x.

Majoul T , Bancel E , Triboi E , Ben Hamida J , Branlard G. Proteomic analysis of the effect of heat stress on hexaploid wheat grain: Characterization of heat-responsive proteins from nonprolamins fraction. Proteomics 2004; 4(2):505513. doi:10.1002/pmic.200300570.

Manaa A , Ben Ahmed H , Valot B , Bouchet JP , Aschi-Smiti S , Causse M , Faurobert M. Salt and genotype impact on plant physiology and root proteome variations in tomato. J. Exp. Bot. 2011; 62(8):27972813. doi:10.1093/jxb/erq460.

Mukhopadhyay A , Vij S , Tyagi A.K. Overexpression of a zinc-finger protein gene from rice confers tolerance to cold, dehydration, and salt stress in transgenic tobacco. Proc. Natl. Acad. Sci. USA 2004; 101:63096314. doi:10.1073/pnas.0401572101.

Munns R. Comparative physiology of salt and water stress. Plant Cell Environ. 2002; 25(2):239250. doi:10.1046/j.0016-8025.2001.00808.x.

Munns R. Genes and salt tolerance: Bringing them together. Tansley Rev. New Phytol. 2005; 167(3):645663. doi:10.1111/j.1469-8137.2005.01487.x.

Munns R , Tester M. Mechanisms of salinity tolerance. Annu. Rev. Plant Biol. 2008; 59:651681. doi:10.1146/annurev.arplant.59.032607.092911.

Ngara R , Ndimba R , Borch-Jensen J , Jensen ON , Ndimba B. Identification and profiling of salinity stress-responsive proteins in Sorghum bicolor seedlings. J. Proteomics 2012; 75:41394150. doi:10.1016/j.jprot.2012.05.038.

Pang Q , Chen S , Dai S , Chen Y , Wang Y , Yan X . Comparative proteomics of salt tolerance in Arabidopsis thaliana and Thellungiella halophila. J. Proteome Res. 2010; 9(5):25842599. doi: 10.1021/pr100034f.

Peng ZY , Wang MC , Li F , Lv HJ , Li CL , Xia G.M. A proteomic study of the response to salinity and drought stress in an introgression strain of bread wheat. Mol. Cell Proteomics 2009; 8(12):26762686. doi:10.1074/mcp.M900052-MCP200.

Ramegowda V , Senthil-Kumar M , Nataraja KN , Reddy MK , Mysore KS , Udayakumar M. Expression of a finger millet transcription factor, EcNAC1, in tobacco confers abiotic stress-tolerance. PLoS ONE 2012; 7(7):e40397. doi:10.1371/journal.pone.0040397.

Rasoulnia A , Bihamta M , Peyghambari S , Alizadeh H , Rahnama A. Proteomic response of barley leaves to salinity. Mol. Biol. Rep. 2010; 38(8):50555063. doi:10.1007/s11033-010-0651-8.

Razavizadeh R , Ehsanpour AA , Ahsan N , Komatsu S. Proteome analysis of tobacco leaves under salt stress. Peptides 2009; 30(9):16511659. doi:10.1016/j.peptides.2009.06.023.

Sengupta S , Majumder A.L. Insight into the salt tolerance factors of a wild halophytic rice, Porteresia coarctata: A physiological and proteomic approach. Planta 2009; 229:911929. doi:10.1007/s00425- 008-0878-y.

Shao QS , Shu S , Du J , Yuan YH , Xing WW , Guo SR , Sun J. Proteome analysis of roots in cucumber seedlings under iso-osmotic NaCl and Ca(NO3)2 stresses. Plant Mol. Biol. Rep. 2016; 34:303317. doi:10.1007/s11105-015-0916-4.

Singh AK , Kumar R , Pareek A , Sopory SK , Singla-Pareek S.L. Overexpression of rice CBS domain containing protein improves salinity, oxidative, and heavy metal tolerance in transgenic tobacco. Mol. Biotechnol. 2012; 52(3):205216. doi:10.1007/s12033-011-9487-2.

Singla-Pareek SL , Reddy MK , Sopory S.K. Genetic engineering of the glyoxalase pathway in tobacco leads to enhanced salinity tolerance. Proc. Natl. Acad. Sci. USA 2003; 100(25):1467214677. doi: 10.1073_pnas.2034667100.

Sobhanian H , Motamed N , Jazii FR , Nakamura T , Komatsu S. Salt stress induced differential proteome and metabolome response in the shoots of Aeluropus lagopoides (Poaceae), a halophyte C4 plant. J. Proteome Res. 2010a; 9(6):28822897. doi:10.1021/pr900974k.

Sobhanian H , Razavizadeh R , Nanjo Y , Ehsanpour AA , Jazii FR , Motamed N , Komatsu S. Proteome analysis of soybean leaves, hypocotyls and roots under salt stress. Proteome Sci. 2010b; 8:19. doi:10.1186/1477-5956-8-19.

Tada Y , Kashimura T. Proteomic analysis of salt-responsive proteins in the mangrove plant, Bruguiera gymnorhiza. Plant Cell Physiol. 2009; 50(3):439446. doi:10.1093/pcp/pcp002.

Tanou G , Job C , Rajjou L , Arc E , Belghazi M , Diamantidis G , Molassiotis A , Job D. Proteomics reveals the overlapping roles of hydrogen peroxide and nitric oxide in the acclimation of citrus plants to salinity. Plant J. 2009; 60(5):795804. doi:10.1111/j.1365-313X.2009.04000.x.

Tyagi H , Jha S , Sharma M , Giri J , Tyagi A.K. Rice SAPs are responsive to multiple biotic stresses and overexpression of OsSAP1, an A20/AN1 zinc-finger protein, enhances the basal resistance against pathogen infection in tobacco. Plant Sci. 2014; 225:6876. doi:10.1016/j.plantsci.2014.05.016.

Veeranagamallaiah G , Jyothsnakumari G , Thippeswamy M , Chandra Obul Reddy P , Surabhi G-K , Sriranganayakulu G , Mahesh Y , Rajasekhar B , Madhurarekha C , Sudhakar C. Proteomic analysis of salt stress responses in foxtail millet (Setaria italica L. cv. Prasad) seedling. Plant Sci. 2008; 175(5):631641. doi:10.1016/j.plantsci.2008.06.017.

292 Vincent D , Ergul A , Bohlman MC , Tattersall EA , Tillett RL , Wheatley MD , Woolsey R , et al. Proteomic analysis reveals differences between Vitis vinifera L. cv. Chardonnay and cv. Cabernet Sauvignon and their responses to water deficit and salinity. J. Exp. Bot. 2007; 58(7):18731892. doi:10.1093/jxb/erm012.

Wakeel A , Asif AR , Pitann B , Schubert S. Proteome analysis of sugar beet (Beta vulgaris L.) elucidates constitutive adaptation during the first phase of salt stress. J. Plant Physiol. 2011; 168(6):519526. doi:10.1016/j.jplph.2010.08.016.

Wang J , Meng Y , Li B , Ma X , Lai Y , Si E , Yang K , et al. Physiological and proteomic analyses of salt stress response in the halophyte Halogeton glomeratus. Plant Cell Environ. 2015; 38: 655669. doi:10.1111/pce.12428.

Wang L , Liu X , Liang M , Tan F , Liang W , Chen Y , Lin Y , Huang L , Xing J , Chen W. Proteomic analysis of salt-responsive proteins in the leaves of Mangrove Kandelia candel during short-term stress. PLoS ONE 2014; 9(1):e83141. doi:10.1371/journal.pone.0083141.

Willey NJ , Heinekamp YJ , Burridge A. Genomic and proteomic analyses of plant response to radiation in the environmentan abiotic stress context. Radioprotection 2009; 44(5):887890. doi:10.1051/radiopro/20095158.

Wong CE , Li Y , Labbe A , Guevara D , Nuin P , Whitty B , Diaz C , et al. Transcriptional profiling implicates novel interactions between abiotic stress and hormonal responses in Thellungiella, a close relative of Arabidopsis. Plant Physiol. 2006; 140(4):14371450. doi:10.1104/pp.105.070508.

Xu CP , Sibicky T , Huang B.R. Protein profile analysis of salt-responsive proteins in leaves and roots in two cultivars of creeping bentgrass differing in salinity tolerance. Plant Cell Rep. 2010; 29(6):595615. doi:10.1007/s00299-010-0847-3.

Xu D , Duan X , Wang B , Hong B , Ho T , Wu R. Expression of a late embryogenesis abundant protein gene, HVA1, from barley confers tolerance to water deficit and salt stress in transgenic rice. Plant Physiol. 1996; 110(1):249257. doi:10.1104/pp.110.1.249.

Yu J , Chen S , Zhao Q , Wang T , Yang C , Diaz C , Sun G , Dai S. Physiological and proteomic analysis of salinity tolerance in Puccinellia tenuiflora. J. Proteome Res. 2011; 10(9):38523870. doi:10.1021/pr101102p.

Zhang H , Han B , Wang T , Chen S , Li H , Zhang Y , Dai S. Mechanisms of plant salt response: Insights from proteomics. J. Proteome Res. 2012; 11(1):4967. doi:10.1021/pr200861w.

Zhang L , Ma XL , Zhang Q , Ma CL , Wang PP , Sun YF , Zhao YX , Zhang H. Expressed sequence tags from a NaCl treated Suaeda salsa cDNA library. Gene 2001; 267(2):193200. doi:10.1016/S0378-1119(01)00403-6.

Zhang YY , Lai JB , Sun SH , Li Y , Liu YY , Liang LM , Chen MS , Xie Q. Comparison analysis of transcripts from the halophyte Thellungiella halophila. J. Integr. Plant Biol. 2008; 50(10):13271335. doi:10.1111/j.1744-7909.2008.00740.x.

Zouari N , Ben Saad R , Legavre T , Azaza J , Sabau X , Jaoua M , Masmoudi K , Hassairi A. Identification and sequencing of ESTs from the halophyte grass Aeluropus littoralis. Gene 2007; 404(12):6169. doi:10.1016/j.gene.2007.08.021.

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Agrawal, G.K. , Rakwal, R. , Iwahashi, H. 2002. Isolation of novel rice (Oryza sativa L.) multiple stress responsive MAP kinase gene, OsMSRMK2, whose mRNA accumulates rapidly in response to environmental cues. Biochem. Biophys. Res. Commun. 294: 10091016.

Alvarado-Gutirrez, A. , Del Real-Monroy, M. , Rodrguez-Guerra, R. , Almanza-Snchez, L. , Lozoya-Gloria, E. , Fraire-Velzquez, S. 2008. A Phaseolus vulgaris EF-hand calcium-binding domain is induced early in the defense response against Colletotrichum lindemuthianum and by abiotic stress: Sequences shared between interacting partners. Physiol. Mol. Plant Pathol. 72: 111121.

Arisz, S.A. 2010. Plant phosphatidic acid metabolism in response to environmental stress. PhD thesis, University of Amsterdam, Amsterdam.

Arisz, S.A. , van Wijk, R. , Roels, W. , Zhu, J.K. , Haring, M.A. , Munnik, T. 2013. Rapid phosphatidic acid accumulation in response to low temperature stress in Arabidopsis is generated through diacylglycerol kinase. Front. Plant Sci. 4: 1.

Bari, R. , Jones, J.D.G. 2009. Role of plant hormones in plant defence responses. Plant Mol. Biol. 69: 473488.
Baxter, A. , Mittler, R. , Suzuki, N. 2014. ROS as key players in plant stress signaling. J. Exp. Bot. 65: 12 291240.
Baxter-Burrell, A., Yang, Z., Springer, P.S., Bailey-Serres, J. 2002. RopGAP4-dependent Rop GTPase rheostat control of Arabidopsis oxygen deprivation tolerance. Science 296: 20262028.
Benderradji, L. , Brini, F. , Amar, S.B. , Kellou, K. , Azaza, J. , Masmoudi, K. , et al. 2011. Sodium transport in the seedlings of two bread wheat (Triticum aestivum L.) genotypes showing contrasting salt stress tolerance. Aust. J. Crop Sci. 5: 233241.
Benschop, J.J. , Mohammed, S. , OFlaherty, M. , Heck, A.J. , Slijper, M. , Menke, F.L. 2007. Quantitative phosphoproteomics of early elicitor signaling in Arabidopsis. Mol. Cell. Proteomics 6: 11981214.
Bhattacharjee S. 2005. Reactive oxygen species and oxidative burst: Roles in stress, senescence and signal transduction in plants. Curr. Sci. 89(7): 11131121.
Block, A. , Schmelz, E. , Jones, J.B. , Klee, H.J. 2005. Coronatine and salicylic acid: The battle between Arabidopsis and Pseudomonas for phytohormone control. Mol. Plant Pathol. 6: 7983.
Bowler, C. , Fluhr, R. 2000. The role of calcium and activated oxygens as signals for controlling cross-tolerance. Trends Plant Sci. 5: 241246.
Burg, H.A. , Takken, F.L. 2010. SUMO-, MAPK-, and resistance protein-signaling converge at transcription complexes that regulate plant innate immunity. Plant Signal. Behav. 5: 15971601.
Cai, X.T. , Xu, P. , Zhao, P.X. , Liu, R. , Yu, L.H. , Xiang, C.B. 2014. Arabidopsis ERF109 mediates cross-talk between jasmonic acid and auxin biosynthesis during lateral root formation. Nat. Commun. 5: 5833.
Capiati, D.A. , Pas, S.M. , Tellez-Inon, M.T. 2006. Wounding increases salt tolerance in tomato plants: Evidence on the participation of calmodulin-like activities in cross-tolerance signalling. J. Exp. Bot. 57(10): 23912400.
Chen, F. , Li, Q. , Sun, L. , He, Z. 2006. The rice 14-3-3 gene family and its involvement in responses to biotic and abiotic stress. DNA Res. 13: 5363.
Chini, A. , Fonseca, S. , Fernandez, G. , Adie, B. , Chico, J.M. , Lorenzo, O. , et al. 2007. The JAZ family of repressors is the missing link in jasmonate signalling. Nature: 448, 666671.
Chuang, H. , Harnrak, A. , Chen, Y. , Hsu, C. 2010. A harpin-induced ethylene-responsive factor regulates plant growth and responses to biotic and abiotic stresses. Biophys. Res. Commun. 402: 410420.
Colcombet, J. , Hirt, H. 2008. Arabidopsis MAPKs: A complex signaling netwo rk involved in multiple biological processes. Biochem. J. 413: 217226.
Correa-Aragunde, N. , Foresi, N. , Lamattina, L. 2015. Nitric oxide is a ubiquitous signal for maintaining redox balance in plant cells: Regulation of ascorbate peroxidase as a case study. J. Exp. Bot. 66: 29132921.
Del Ro, L.A. 2015. ROS and RNS in plant physiology: An overview. J. Exp. Bot. 66: 28272837.
Delage, E. , Puyaubert, J. , Zachowski, A. , Ruelland, E. 2013. Signal transduction pathways involving phosphatidylinositol 4-phosphate and phosphatidylinositol 4,5-bisphosphate: Convergences and divergences among eukaryotic kingdoms. Prog. Lipid Res. 52: 114.
Delaunay, A., Pflieger, D., Barrault, M.B., Vinh, J., Toledano, M.B. 2002. A thiol peroxidase is an H2O2 receptor and redox-transducer in gene activation. Cell 111: 471481.
Demkura, P.V. , Abdala, G. , Baldwin, I.T. , Ballare, C.L. 2010. Jasmonate-dependent and -independent pathways mediate specific effects of solar ultraviolet B radiation on leaf phenolics and antiherbivore defense. Plant Physiol. 152: 10841095.
Desikan, R. , A-H-Mackerness, S. , Hancock, J.T. , Neill, S.J. 2001. Regulation of the Arabidopsis transcriptome by oxidative stress. Plant Physiol. 127: 159172.
DeWald, D.B. , Torabinejad, J. , Jones, C.A. , Shope, J.C. , Cangelosi, A.R. , Thompson, J.E. , et al. 2001. Rapid accumulation of phosphatidylinositol 4,5-bisphosphate and inositol 1,4,5-trisphosphate correlates with calcium mobilization in salt-stressed arabidopsis. Plant Physiol. 126: 759769.
307 Drissner, D. , Kunze, G. , Callewaert, N. , Gehrig, P. , Tamasloukht, M. , Boller, T. , et al. 2007. Lyso-phosphatidylcholine is a signal in the arbuscular mycorrhizal symbiosis. Science 318: 265268.
Droillard, M.J. , Boudsocq, M. , Barbier-Brygoo, H. , Lauriere, C. 2004. Involvement of MPK4 in osmotic stress response pathways in cell suspensions and plantlets of Arabidopsis thaliana: Activation by hypoosmolarity and negative role in hyperosmolarity tolerance. FEBS Lett. 574: 4248.
Fahad, S. , Hussain, S. , Bano, A. , Saud, S. , Hassan, S. , Shan, D. , et al. 2015. Potential role of phytohormones and plant growth-promoting rhizobacteria in abiotic stresses: Consequences for changing environment. Environ. Sci. Pollut. Res. 22: 49074921.
Fahad, S. , Hussain, S. , Matloob, A. , Khan, F.A. , Khaliq, A. , Saud, S. , et al. 2015. Phytohormones and plant responses to salinity stress: A review. Plant Growth Regul. 75: 391404.
Finka, A. , Cuendet, A.F. , Maathuis , F.J. , Saidi, Y. , Goloubinoff, P. 2012. Plasma membrane cyclic nucleotide gated calcium channels control land plant thermal sensing and acquired thermotolerance. Plant Cell 24: 33333348.
Foo, E. , Davies, N.W. 2011. Strigolactones promote nodulation in pea. Planta 234: 10731081.
Foyer, C.H. , Noctor, G. 2003. Redox sensing and signalling associated with reactive oxygen in chloroplasts, peroxisomes and mitochondria. Physiol. Planta. 119(3): 355364.
Fraire-Velzquez, S. , Rodrguez-Guerra, R. , Snchez-Caldern, L. 2011. Abiotic and biotic stress response crosstalk in plants. In: Abiotic Stress Response in Plants Physiological, Biochemical and Genetic Perspectives, Arun Shanker and B. Venkateswarlu (Eds.), pp. 325. ISBN 978-953-307-672-0.
Froidure, S. , Canonne, J. , Daniel, X. , Jauneau, A. , Briere, C. , Roby, D. , Rivas, S. 2010. AtsPLA2-alpha nuclear relocalization by the Arabidopsis transcription factor AtMYB30 leads to repression of the plant defense response. Proc. Natl. Acad. Sci. USA 107: 1528115286.
Gadjev, I. , Vanderauwera, S. , Gechev, T.S. , Laloi, C. , Minkov, I.N. , Shulaev, V. , et al. 2006. Transcriptomic footprints disclose specificity of reactive oxygen species signaling in Arabidopsis. Plant Physiol. 141: 436445.
Gaude, N. , Nakamura, Y. , Scheible, W.R. , Ohta, H. , Dormann, P. 2008. Phospholipase C5 (NPC5) is involved in galactolipid accumulation during phosphate limitation in leaves of Arabidopsis. Plant J. 56: 2839.
Geisler, A.C. , Rudolph, T.K. 2012. NitroalkylationA redox sensitive signaling pathway. Biochim. Biophys. Acta 1820: 777784.
Gill, S.S., Tuteja, N. 2010. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants, Plant Physiol. Biochem. 48: 909930.
Glauser, G. , Dubugnon, L. , Mousavi, S.A. , Rudaz, S. , Wolfender, J.L. , Farmer, E.E. 2009. Velocity estimates for signal propagation leading to systemic jasmonic acid accumulation in wounded Arabidopsis. J. Biol. Chem. 284: 3450634513.
Gomi, K. , Ogawa, D. , Katou, S. , Kamada, H. , Nakajima, N. , Saji, H. , et al. 2005. A mitogen-activated protein kinase NtMPK4 activated by SIPKK is required for jasmonic acid signaling and involved in ozone tolerance via stomatal movement in tobacco. Plant Cell Physiol. 46: 19021914.
Gudesblat, G.E. , Iusem, N.D. , Morris, P.C. 2007. Guard cell-specific inhibition of Arabidopsis MPK3 expression causes abnormal stomatal responses to abscisic acid and hydrogen peroxide. New Phytol. 173: 713721.
Guillas, I. , Guellim, A. , Reze, N. , Baudouin, E. 2013. Long chain base changes triggered by a short exposure of Arabidopsis to low temperature are altered by AHb1 non-symbiotic haemoglobin overexpression. Plant Physiol. Biochem. 63: 191195.

Guo, L. , Devaiah, S.P. , Narasimhan, R. , Pan, X. , Zhang, Y. , Zhang, W. , et al. 2012a. Cytosolic glyceraldehyde-3-phosphate dehydrogenases interact with phospholipase D delta to transduce hydrogen peroxide signals in the Arabidopsis response to stress. Plant Cell 24: 22002212.
Guo, L. , Mishra, G. , Markham, J.E. , Li, M. , Tawfall, A. , Welti, R. , et al. 2012b. Connections between sphingosine kinase and phospholipase D in the abscisic acid signaling pathway in Arabidopsis. J. Biol. Chem. 287: 82868296.
Guo, Y. , Xiong, L. , Ishitani, M. , Zhu, J.K. 2002. An Arabidopsis mutation in translation elongation factor 2 causes superinduction of CBF/DREB1 transcription factor genes but blocks the induction of their downstream targets under low temperatures. Proc. Natl. Acad. Sci. USA 99: 77867791.
Gupta, M. , Sharma, P. , Sarin, N.B. , Sinha, A.K. 2009. Differential response of arsenic stress in two varieties of Brassica juncea L. Chemosphere 74: 12011208.
Hamel, L.P. , Miles, G.P. , Samuel, M.A. , Ellis, B.E. , Seguin, A. , Beaudoin, N. 2005. Activation of stress-responsive mitogen activated protein kinase pathways in hybrid poplar (Populus trichocarpa Populus deltoides). Tree Physiol. 25: 277288.
Harrison, M.A. 2012. Cross-talk between phytohormone signaling pathways under both optimal and stressful environmental conditions. In: Phytohormones and Abiotic Stress Tolerance in Plants, N.A. Khan , R. Nazar , N. Iqbal , N.A. Anjum (Eds.), Springer-Verlag, Berlin/Heidelberg, pp. 4976.
Helling, D. , Possart, A. , Cottier, S. , Klahre, U. , Kost, B. 2006. Pollen tube tip growth depends on plasma membrane polarization mediated by tobacco PLC3 activity and endocytic membrane recycling. Plant Cell 18: 35193534.
Hirt, H. , Garcia, A.V. , Oelmller, R. 2011. AGC kinases in plant development and defense. Plant Signal. Behav. 6: 10301033.
Hong, Y. , Devaiah, S.P. , Bahn, S.C. , Thamasandra, B.N. , Li, M. , Welti, R. , et al. 2009. Phospholipase D epsilon and phosphatidic acid enhance Arabidopsis nitrogen signaling and growth. Plant J. 58: 376387.
Hou, X. , Lee, L.Y. , Xia, K. , Yan, Y. , Yu, H. 2010. DELLAs modulate jasmonate signaling via competitive binding to JAZs. Dev. Cell 19: 884894.
Huang, D. , Wu, W. , Abrams, S.R. , Adrian, J. , Cutler, A.J. 2008. The relationship of drought-related gene expression in Arabidopsis thaliana to hormonal and environmental factors. J. Exp. Bot. 59: 29913007.
Huang, X. , Li, J. , Bao, F. , Zhang, X. , Yang, S. 2010. A gain-of-function mutation in the Arabidopsis disease resistance gene RPP4 confers sensitivity to low temperature. Plant Physiol. 154: 796809.
Ichimura, K. , Mizoguchi, T. , Irie, K. , Morris, P. , Giraudat, J. , Matsumoto, K. , et al. 1998. Isolation of ATMEKK1 (a MAP Kinase kinase kinase)-interacting proteins and analysis of a MAP kinase cascade in Arabidopsis. Biochem. Biophys. Res. Commun. 253: 532543.
Ichimura, K. , Mizoguchi, T. , Yoshida, R. , Yuasa, T. , Shinozaki, K. 2000. Various abiotic stresses rapidly activate Arabidopsis MAP kinases ATMPK4 and ATMPK6. Plant J. 24: 655665.
308 Jonak, C. , Kiegerl, S. , Ligterink, W. , Barker, P.J. , Huskisson, N.S. , Hirt, H. 1996. Stress signaling in plants: A mitogen-activated protein kinase pathway is activated by cold and drought. Proc. Natl. Acad. Sci. USA 93: 1127411279.
Jonak, C. , Nakagami, H. , Hirt, H. 2004. Heavy metal stress. Activation of distinct mitogen-activated protein kinase pathways by copper and cadmium. Plant Physiol. 136: 32763283.
Jones, J.D. , Dangl, J.L. 2006. The plant immune system. Nature 444: 323329.
Jung, H.W. , Tschaplinski, T.J. , Wang, L. , Glazebrook, J. , Greenberg, J.T. 2009. Priming in systemic plant immunity. Science 324: 89 89.
Kachroo, A. , Kachroo, P. 2009. Fatty acid-derived signals in plant defense. Annu. Rev. Phytopathol. 47: 153176.
Kalachova, T. , Iakovenko, O. , Kretinin, S. , Kravets, V. 2013. Involvement of phospholipase D and NADPH-oxidase in salicylic acid signaling cascade. Plant Physiol. Biochem. 66: 127133.
Karpinski, S. , Szechynska-Hebda, M. , Wituszynska, W. , Burdiak, P. 2013. Light acclimation, retrograde signalling, cell death and immune defences in plants. Plant Cell Environ. 36: 736744.
Khan, S. , Stone, J.M. 2007. Arabidopsis thaliana GH3.9 in auxin and jasmonate crosstalk. Plant Signal. Behav. 2: 483485.
Kimura, S. , Kaya, H. , Kawarazaki, T. , Hiraoka, G. , Senzaki, E. , Michikawa, M. , et al. 2012. Protein phosphorylation is a prerequisite for the Ca2+-dependent activation of Arabidopsis NADPH oxidases and may function as a trigger for the positive feedback regulation of Ca2+ and reactive oxygen species. Biochim. Biophys. Acta. 1823: 398405.
Kitagawa, M. , Jackson D. 2017. Plasmodesmata-mediated cell-to-cell communication in the shoot apical meristem: How stem cells talk. Plants 6(12): 114.
Koltai, H. , Beveridge, C.A. 2013. Strigolactones and the coordinated development of shoot and root. In: Long-Distance Systemic Signaling and Communication in Plants, F. Baluska (Ed.), Springer, Berlin, pp. 189204.
Konigshofer, H. , Tromballa, H.W. , Loppert, H.G. 2008. Early events in signalling high-temperature stress in tobacco BY2 cells involve alterations in membrane fluidity and enhanced hydrogen peroxide production. Plant Cell Environ. 31: 17711780.
Kwak, J.M. , Mori, I.C. , Pei, Z.M. , Leonhardt, N. , Torres, M.A. , Dangl, J.L. , et al. 2003. NADPH oxidase AtrbohD and AtrbohF genes function in ROS-dependent ABA signaling in Arabidopsis. EMBO J. 22: 26232633.
Lachaud, C., Prigent, E., Thuleau, P., Grat, S., Da Silva, D., Brire, C., et al. 2013. 14-3-3-Regulated Ca2+-dependent protein kinase CPK3 is required for sphingolipid-induced cell death in Arabidopsis. Cell Death Differ. 20: 209217.
Lanteri, M.L. , Laxalt, A.M. , Lamattina, L. 2008. Nitric oxide triggers phosphatidic acid accumulation via phospholipase D during auxin induced adventitious root formation in cucumber. Plant Physiol. 147: 188198.
Lee, B.H. , Won, S.H. , Lee, H.S. , Miyao, M. , Chung, W.I. , Kim, I.J. 2000. Expression of the chloroplast-localized small heat shock protein by oxidative stress in rice. Gene 245(2): 283290.
Lee, S. , Hirt, H. , Lee, Y. 2001. Phosphatidic acid activates a wound-activated MAPK in Glycine max. Plant J. 26: 479486.
Li, M. , Hong, Y. , Wang, X. 2009. Phospholipase D- and phosphatidic acid-mediated signaling in plants. Biochim. Biophys. Acta 1791: 927935.
Li, P. , Chen, L. , Zhou, Y. , Xia, X. , Shi, K. , Chen, Z. , et al. 2013. Brassinosteroids-induced systemic stress tolerance was associated with increased transcripts of several defence-related genes in the phloem in Cucumis sativus. PLoS One 8: 66582.
Ligterink, W. , Hirt, H. 2001. Mitogen-activated protein (MAP) kinase pathways in plants: Versatile signaling tools. Int. Rev. Cytol. 201: 209275.
Ling, H.H. 2015. Functional roles of plant protein kinases in signal transduction pathways during abiotic and biotic stress. J. Biodivers. Biopros. Dev. 2: 147.
Loeffler, C. , Berger, S. , Guy, A. , Durand, T. , Bringmann, G. , Dreyer, M. , et al. 2005. B1- phytoprostanes trigger plant defense and detoxification responses. Plant Physiol. 137: 328340.
Luna, E. , Pastor, V. , Robert, J. , Flors, V. , Mauch-Mani, B. , Ton, J. 2011. Callose deposition: A multifaceted plant defense response. Mol. Plant Microbe Interact. 24: 183193.
Mackerness, S.A.H. , Surplus, S.L. , Blake, P. , John, C.F. , Buchanan-Wollaston, V. , Jordan, B.R. , et al. 1999. Ultraviolet-B-induced stress and changes in gene expression in Arabidopsis thaliana: Role of signaling pathways controlled by jasmonic acid, ethylene and reactive oxygen species. Plant Cell Environ. 22: 14131423.
Mandal, M.K. , Chandra-Shekara, A.C. , Jeong, R.D. , Yu, K. , Zhu, S. , Chanda, B. , et al. 2012. Oleic acid-dependent modulation of NITRIC OXIDE ASSOCIATED1 protein levels regulates nitric oxide-mediated defense signaling in Arabidopsis. Plant Cell 24: 16541674.

Marinho, H.S. , Real, C. , Cyrne, L. , Soares, H. , Antunes, F. 2014. Hydrogen peroxide sensing, signaling and regulation of transcription factors. Redox Biol. 2: 3562.

Markham, J.E. , Lynch, D.V. , Napier, J.A. , Dunn, T.M. , Cahoon, E.B. 2013. Plant sphingolipids: Function follows form. Curr. Opin. Plant Biol. 16: 350357.

Mata-Prez, C. , Snchez-Calvo, B. , Begara-Morales, J.C. , Luque, F. , Jimnez-Ruiz, J. , Padilla, M.N. , et al. 2015. Transcriptomic profiling of linolenic acid-responsive genes in ROS signaling from RNA-seq data in Arabidopsis. Front. Plant Sci. 6: 122.

McLoughlin, F., Arisz, S.A., Dekker, H.L., Kramer, G., De Koster, C.G., Haring, M.A., et al. 2013. Identification of novel candidate phosphatidic acid-binding proteins involved in the salt-stress response of Arabidopsis thaliana roots. Biochem. J. 450: 573581.

Mengiste, T. , Chen, X. , Salmeron, J. , Dietrich, R. 2003. The BOS1 gene encodes an R2R3MYB transcription factor protein that is required for biotic and abiotic stress responses in arabidopsis. The Plant Cell. Online.

Miles, G.P. , Samuel, M.A. , Zhang, Y. , Ellis, B.E. 2005. RNA interference-based (RNAi) suppression of AtMPK6, an Arabidopsis mitogen-activated protein kinase, results in hypersensitivity to ozone and misregulation of AtMPK3. Environ. Pollut. 138: 230237.

Mishra, G. , Zhang, W. , Deng, F. , Zhao, J. , Wang, X. 2006. A bifurcating pathway directs abscisic acid effects on stomatal closure and opening in Arabidopsis. Science 312: 264266.

Misson, J. , Raghothama, K.G. , Jain, A. , Jouhet, J. , Block, M.A. , Bligny, R. , et al. 2005. A genome-wide transcriptional analysis using Arabidopsis thaliana Affymetrix gene chips determined plant responses to phosphate deprivation. Proc. Natl. Acad. Sci. USA 102: 1193411939.

309 Moller, I.M. 2001. Plant mitochondria and oxidative stress: Electron transport, NADPH turnover, and metabolism of reactive oxygen species. Ann. Rev. Plant Physiol. Plant Mol. Biol. 52(1): 561591.

Munoz-Snchez, J.A. , Altzar-Molina, A. , Teresa Hernndez-Sotomayor, S.M. 2012. Phospholipase signaling is modified differentially by phytoregulators in Capsicum chinense J. cells. Plant Signal. Behav. 7: 11031105.

Munnik T , Nielsen E. 2011. Green light for polyphosphoinositide signals in plants. Curr. Opin. Plant Biol. 14: 489497.

Munnik, T. , Vermeer, J.E.M. 2010. Osmotic stress-induced phosphoinositide and inositol phosphate signalling in plants. Plant Cell Environ. 33(4): 655659.

Ning, J. , Li, X. , Hicks, L.M. , Xiong, L. 2010. A Raf-like MAPKKK gene DSM1 mediates drought resistance through reactive oxygen species scavenging in rice. Plant Physiol. 152: 876890.

OBrien, J.A. , Benkova, E. 2013. Cytokinin cross-talking during biotic and abiotic stress responses. Front. Plant Sci. 4: 451.

Ohashi, Y. , Oka, A. , Rodrigues-Pousada, R. , Possenti, M. , Ruberti, I. , Morelli, G. , et al. 2003. Modulation of phospholipid signaling by GLABRA2 in root-hair pattern formation. Science 300: 14271430.

Okazaki, Y. , Saito, K. 2014. Roles of lipids as signaling molecules and mitigators during stress response in plants. Plant J. 79: 584596.

Okazaki, Y. , Otsuki, H. , Narisawa, T. , Kobayashi, M. , Sawai, S. , Kamide, Y. , et al. 2013. A new class of plant lipid is essential for protection against phosphorus depletion. Nat. Commun. 4: 1510.

Pareek, A. , Sopory, S.K. , Bohnert, H.J. , Govindjee, M.A.L. (Eds.). 2010. Abiotic Stress Adaptation in Plants. Springer, Dordrecht.

Park, S.W. , Li, W. , Viehhauser, A. , He, B. , Kim, S. , Nilsson, A.K. , et al. 2013. Cyclophilin 20-3 relays a 12-oxo-phytodienoic acid signal during stress responsive regulation of cellular redox homeostasis. Proc. Natl. Acad. Sci. USA 110: 95599564.

Peters, C. , Li, M. , Narasimhan, R. , Roth, M. , Welti, R. , Wang, X. 2010. Nonspecific phospholipase C NPC4 promotes responses to abscisic acid and tolerance to hyperosmotic stress in Arabidopsis. Plant Cell 22: 26422659.

Petrov, V.D. , Van Breusegem, F. 2012. Hydrogen peroxidea central hub for information flow in plant cells. AoB Plants 2012:ls014. doi:10.1093/aobpla/pls014.

Pleskot, R. , Li, J. , Zrsky, V. , Potocky, M. , Staiger, C.J. 2013. Regulation of cytoskeletal dynamics by phospholipase D and phosphatidic acid. Trends Plant Sci. 18: 496504.

Pokotylo, I. , Kolesnikov, Y. , Kravets, V. , Zachowski, A. , Ruelland, E. 2014. Plant phosphoinositide-dependent phospholipases C: Variations around a canonical theme. Biochimie 96: 144157.

Pospilov, J. 2003. Participation of phytohormones in the stomatal regulation of gas exchange during water stress. Biol. Plant. 46: 491506.

Qi, T. , Song, S. , Ren, Q. , Wu, D. , Huang, H. , Chen, Y. , et al. 2011. The jasmonate-ZIM-domain proteins interact with the WD-Repeat/bHLH/MYB complexes to regulate Jasmonate-mediated anthocyanin accumulation and trichome initiation in Arabidopsis thaliana. Plant Cell 23: 17951814.

Raho, N. , Ramirez, L. , Lanteri, M.L. , Gonorazky, G. , Lamattina, L. , Ten, H.A. , et al. 2011. Phosphatidic acid production in chitosan elicited tomato cells, via both phospholipase D and phospholipase C/diacylglycerol kinase, requires nitric oxide. J. Plant Physiol. 168: 534539.

Ramakrishna, A., Ravishankar, G.A. 2011. Influence of abiotic stress singles on secondary metabolites in plants. Plant Signal Behav 6:17201731.

Ramos-Diaz, A. , Brito-Argaez, L. , Munnik, T. , Hernandez-Sotomayor, S.M. 2007. Aluminum inhibits phosphatidic acid formation by blocking phospholipase C pathway. Planta 225: 393401.

Rasmusson, A.G. , Soole, K.L. , Elthon, T.E. 2004. Alternative NAD (P) H dehydrogenases of plant mitochondria. Annu. Rev. Plant Biol. 55(1): 2339.

Rejeb, I.B. , Pastor, V. , Mauch-Mani, B. 2014. Plant responses to simultaneous biotic and abiotic stress: Molecular mechanisms. Plants. 3: 458475.

Ren, D. , Liu, Y. , Yang, K.Y. , Han, L. , Mao, G. , Glazebrook, J. , et al. 2008. A fungal-responsive MAPK cascade regulates phytoalexin biosynthesis in Arabidopsis. Proc. Natl. Acad. Sci. USA 105: 56385643.

Riemann, M. , Dhakarey, R. , Hazman, M. , Miro, B. , Kohli, A. , Nick, P. 2015. Exploring jasmonates in the hormonal network of drought and salinity responses. Front. Plant Sci. 6: 1077.

Rudolph, V. , Schopfer, F.J. , Khoo, N.K. , Rudolph, T.K. , Cole, M.P. , Woodcock, S.R. , et al. 2009. Nitro-fatty acid metabolome: Saturation, desaturation, -oxidation, and protein adduction. J. Biol. Chem. 284: 14611473.

Ruelland, E. , Kravets, V. , Derevyanchuk, M. , Martinec, J. , Zachowski, A. , Pokotylo, I. 2015. Role of phospholipid signalling in plant environmental responses. Environ. Exp. Bot. 114: 129143. doi:10.1016/j.envexpbot.2014.08.009.

Saucedo-Garcia, M. , Guevara-Garcia, A. , Gonzalez-Solis, A. , Cruz-Garcia, F. , Vazquez-Santana, S. , Markham, J.E., et al. 2011. MPK6, sphinganine and the LCB2a gene from serine palmitoyltransferase are required in the signaling pathway that mediates cell death induced by long chain bases in Arabidopsis. New Phytol. 191(4): 943957.

Seo, S. , Okamoto, M. , Seto, H. , Ishizuka, K. , Sano, H. , Ohashi, Y. 1995. Tobacco MAP kinase: A possible mediator in wound signal transduction pathways. Science 270: 19881992.

Shah, J. , Zeier, J. 2013. Long-distance communication and signal amplification in systemic acquired resistance. Front. Plant. Sci. 4: 30.

Sheard, L.B. , Tan, X. , Mao, H. , Withers, J. , Ben-Nissan, G. , Hinds, T.R. , et al. 2010. Jasmonate perception by inositol-phosphate-potentiated COI1-JAZ co-receptor. Nature 468: 400405.

Sinha, A.K. , Jaggi, M. , Raghuram, B. , Tuteja, N. 2011. Mitogen-activated protein kinase signaling in plants under abiotic stress. Plant Signal. Behav. 6(2): 196203.

Soler, R. , Erb, M. , Kaplan, I. 2013. Long distance rootshoot signalling in plantinsect community interactions. Trends Plant Sci. 18: 149156.

Stamm, P. , Kumar, P.P. 2013. Auxin and gibberellin responsive Arabidopsis SMALL AUXIN UP RNA36 regulates hypocotyl elongation in the light. Plant Cell Rep. 32: 759769.

Suarez-Rodriguez, M.C. , Adams-Phillips, L. , Liu, Y. , Wang, H. , Su, S.H. , J ester, P.J. , et al. 2007. MEKK1 is required for flg22-induced MPK4 activation in Arabidopsis plants. Plant Physiol. 143: 661669.

Suzuki, N. , Miller, G. , Salazar, C. , Mondal, H.A. , Shulaev, E. , Cortes, D.F. , et al. 2013. Temporal-spatial interaction between reactive oxygen species and abscisic acid regulates rapid systemic acclimation in plants. Plant Cell. 25: 35533569.

310 Suzuki, N. , Mittler, R. 2012. Reactive oxygen species-dependent wound responses in animals and plants. Free Radic. Biol. Med. 53: 22692276.

Taiz, L. , Zeiger, E. 2010. Plant Physiology, 5th edition. Sinauer Associates, USA.

Takekawa, M. , Tatebayashi, K. , Saito, H. 2005. Conserved docking site is essential for activation of mammalian MAP kinase kinases by specific MAP kinase kinase kinases. Mol. Cell. 5(18): 295306.

Taki, N. , Sasaki-Sekimoto, Y. , Obayashi, T. , Kikuta, A. , Kobayashi, K. , Ainai, T. , et al. 2005. 12-oxo-phytodienoic acid triggers expression of a distinct set of genes and plays a role in wound-induced gene expression in Arabidopsis. Plant Physiol. 139: 12681283.

Tanou, G. , Job, C. , Belghazi, M. , Molassiotis, A. , Diamantidis, G. , Job, D. 2010. Proteomic signatures uncover hydrogen peroxide and nitric oxide cross-talk signaling network in citrus plants. J. Proteome Res. 9: 59946006.

Teige, M. , Scheikl, E. , Eulgem, T. , Doczi, R. , Ichimura, K. , Shinozaki, K. , et al. 2004. The MKK2 pathway mediates cold and salt stress signaling in Arabidopsis. Mol. Cell. 15: 141152.

Testerink, C. , Larsen, P.B. , van der Does, D. , van Himbergen, J.A.J. , Munnik, T. 2007. Phosphatidic acid binds to and inhibits the activity of Arabidopsis CTR1. J. Exp. Bot. 58: 39053914.

Tiryaki, I. , Staswick, P.E. 2002. An Arabidopsis mutant defective in jasmonate response is allelic to the auxin-signaling mutant axr1. Plant Physiol. 130: 887894.

Tsutsui, T. , Kato, W. , Asada, Y. , Sako, K. , Sato, T. , Sonoda, Y. , et al. 2009. DEAR1, a transcriptional repressor of DREB protein that mediates plant defense and freezing stress responses in Arabidopsis. J. Plant Res. 122: 633643.

Ulm, R. , Ichimura, K. , Mizoguchi, T. , Peck, S.C. , Zhu, T. , Wang, X. , et al. 2002. Distinct regula tion of salinity and genotoxic stress responses by Arabidopsis MAP kinase phosphatase 1. EMBO J. 21: 64836493.

Uraji, M. , Katagiri, T. , Okuma, E. , Ye, W. , Hossain, M.A. , Masuda, C. , et al. 2012. Cooperative function of PLDdelta and PLDalpha1 in abscisic acid-induced stomatal closure in Arabidopsis. Plant Physiol. 159: 450460.

Viehweger, K. , Dordschbal, B. , Roos, W. 2002. Elicitor-activated phospholipase A(2) generates lysophosphatidylcholines that mobilize the vacuolar H(+) pool for pH signaling via the activation of Na (+)-dependent proton fluxes. Plant Cell 14: 15091525.

Vranov, E. , Atichartpongkul, S. , Villarroel, R. , Van Montagu, M. , Inz, D. , Van Camp, W. 2002. Comprehensive analysis of gene expression in Nicotiana tabacum leaves acclimated to oxidative stress. Proc. Natl. Acad. Sci. USA 99: 1087010875.

Vurro, M. , Yoneyama, K. 2012. Strigolactonesintriguing biologically active compounds: Perspectives for deciphering their biological role and for proposing practical application, Pest Manage. Sci. 68: 664668.

Walia, H. , Wilson, C. , Wahid, A. , Condamine, P. , Cui, X. , Close, T.J. 2006. Expression analysis of barley (Hordeum vulgare L.) during salinity stress, Funct. Integr. Genom. 6: 143156.

Wang, M. , Zhang, Y. , Wang, J. , Wu, X. , Guo, X. 2007. A novel MAP kinase gene in cotton (Gossypium hirsutum L.), GhMAPK, is involved in response to diverse environmental stresses. J. Biochem. Mol. Biol. 40: 325332.

Wani, S.H. , Kumar, V. , Shriram, V. , Sah, S.K. 2016. Phytohormones and their metabolic engineering for abiotic stress tolerance in crop plants. Crop J. 4(3): 162176.

Welti, R. , Li, W. , Li, M. , Sang, Y. , Biesiada, H. , Zhou, H.E. , et al. 2002. Profiling membrane lipids in plant stress responses. Role of phospholipase D alpha in freezing-induced lipid changes in Arabidopsis. J. Biol. Chem. 277: 3199432002.

Werner, T. , Nehnevajova, E. , Kollmer, I. , Novak, O. , Strnad, M. , Kramer, U. , et al. 2010. Root-specific reduction of cytokinin causes enhanced root growth, drought tolerance, and leaf mineral enrichment in Arabidopsis and tobacco. Plant Cell 22: 39053920.

Wild, M. , Davire, J.M. , Cheminant, S. , Regnault, T. , Baumberger, N. , Heintz, D. , et al. 2012. The Arabidopsis DELLARGA-LIKE3 is a direct target of MYC2 and modulates jasmonate signaling responses. Plant Cell 24: 33073319.

Wilkinson, S. , Davies, W.J. 2009. Ozone suppresses soil drying and abscisic acid (ABA)-induced stomatal closure via an ethylene-dependent mechanism. Plant Cell Environ. 32: 949959.

Xia, X.J. , Zhou, Y.H. , Shi, K. , Zhou, J. , Foyer, C.H. , Yu, J.Q. 2015. Interplay between reactive oxygen species and hormones in the control of plant development and stress tolerance. J. Exp. Bot. 66(10): 28392856.

Xing, T. , Malik, K. , Martin, T. , Miki, B.L. 2001. Activation of tomato PR and wound-related genes by a mutagenized tomato MAP kinase kinase through divergent pathways. Plant Mol. Biol. 46: 109120.

Xiong, L. , Zhu, J-K. 2002. Molecular and genetic aspects of plant responses to osmotic stress. Plant Cell Environ. 25(2): 131139.

Yang, W.Y. , Zheng, Y. , Bahn, S.C. , Pan, X.Q. , Li, M.Y. , Vu, H.S. , et al. 2012. The patatin-containing phospholipase A PLAII alpha modulates oxylipin formation and water loss in Arabidopsis thaliana. Mol. Plant. 5: 452460.

Zhang, Q. , Lin, F. , Mao, T. , Nie, J. , Yan, M. , Yuan, M. , et al. 2012. Phosphatidic acid regulates microtubule organization by interacting with MAP65-1 in response to salt stress in Arabidopsis. Plant Cell 24: 45554576.

Zhang, S. , Du, H. , Klessig, D.F. 1998. Activation of the tobacco SIP kinase by both a cell wall-derived carbohydrate elicitor and purified proteinaceous elicitins from Phytophthora spp. Plant Cell 10: 435450.

Zhang, W. , Wang, C. , Qin, C. , Wood, T. , Olafsdottir, G. , Welti, R. , et al. 2003. The oleate-stimulated phospholipase D, PLDdelta, and phosphatidic acid decrease H2O2-induced cell death in Arabidopsis. Plant Cell 15: 22852295.

Zhang, X. , Zhang, L. , Dong, F. , Gao, J. , Galbraith, D.W. 2001. Hydrogen peroxide is involved in abscisic acid-induced stomatal closure in Vicia faba. Plant Physiol. 126(4): 14381448.

Zhang, Y. , Zhu, H. , Zhang, Q. , Li, M. , Yan, M. , Wang, R. , et al. 2009. Phospholipase D alpha1 and phosphatidic acid regulate NADPH oxidase activity and production of reactive oxygen species in ABA-mediated stomatal closure in Arabidopsis. Plant Cell 21: 23572377.

Zhu, S.Y. , Yu, X.C. , Wang, X.Y. , Zhao, R. , Li, Y. , Fan, R.C. , et al. 2007. Two calcium-dependent protein kinases, CPK4 and CPK11, regulate abscisic acid signal transduction in Arabidopsis. Plant Cell 19: 30193036.

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Abbaspour, S. H. and H. Rezaei . 2014. Effects of salicylic acid and jasmonic acid on hill reaction and photosynthetic pigment (Dracocephalum Moldavica L.) in different levels of drought. International Journal of Advanced Biological and Biomedical Research 2 (12): 2850 2850.

Abdelgawad, Z. A. , A. A. Khalafaallah , and M. M. Abdallah . 2014. Impact of methyl jasmonate on antioxidant activity and some biochemical aspects of maize plant grown under water stress condition. Agriculture Science 5(October): 1077 1077.

321 Abe, M. , H. Shiboaka , and H. Yamane . 1990. Cell cycle-dependent disruption of microtubules by methyl jasmonate in tobacco BY-2 cells. Protoplasma 156:18.

Acosta, I. F. and E. E. Farmer . 2010. Jasmonates. The Arabidopsis Book 8: e0129.

Aldridge, D. C. , S. Galt , and D. Giles. 1971. Metabolites of Lasiodiplodia theobromae. Journal of the Chemical Society. (C), 16231627.

Ali, M. B. , E. J. Hahn , and K. Y. Paek . 2007. Methyl jasmonate and salicylic acid induced oxidative stress and accumulation of phenolics in Panax ginseng bioreactor root suspension cultures. Molecules. 12(3): 607621.

Allakhverdiev, S. I. , Y. Nishiyama , S. Miyairi , et al. 2002. Salt stress inhibits the repair of photodamaged photosystem II by suppressing the transcription and translation of psbA genes in Synechocystis. Plant Physiology 130: 14431453.

Ananiev, E. D. , K. Ananieva , and I. Todorov . 2004. Effects of methyl ester of jasmonic acid, abscisic acid and benzyladenine on chlorophyll synthesis in excised cotyledons of Cucurbita pepo (Zucchini). Bulgarian Journal of Plant Physiology 30: 5163.

Andreou, A. and I. Feussner . 2009. Lipoxygenases structure and reaction mechanism. Phytochemistry 70: 15041510.

Andreou, A. , F. Brodhun , and I. Feussner . 2009. Biosynthesis of oxylipins in non-mammals. Progress in Lipid Research 48:148170.

Aro, E. M. , I. Virgin , and B. Andersson .1993. Photoinhibition of photosystem II. Inactivation, protein damage and turnover. Biochimica et Biophysica Acta 1143: 113134.

Asada, K. 1999. The water-water cycle in chloroplasts: Scavenging of active oxygen species and dissipation of excess photons. Annual Review of Plant Biology 50: 601639.

Babst, B. A. , R. A. Ferrieri , D. W. Gray , et al. 2005. Jasmonic acid induced rapid changes in carbon transport and partitioning in Populus. New Phytologist 167: 6372.

Bachmann, A. , B. Hause , H. Maucher , et al. 2002. Jasmonate-induced lipid peroxidation in barley leaves initiated by distinct 13-LOX forms of chloroplasts. Journal of Biological Chemistry 383: 16451657.

Baginsky, S. , K. Tiller , T. Pfannschmidt , et al. 1999. PTK, the chloroplast RNA polymerase-associated protein kinase from mustard (Sinapis alba), mediates redox control of plastid in vitro transcription. Plant Molecular Biology 39: 10131023.

Beale, S. I. 1978. -Aminolevulinic acid in plants: Its bio-synthesis, regulation and role in plastid development. Annual Review Plant Physiology 29: 95120.

Berestetzky, V. , W. Dathe , T. Daletskaya , et al. 1991. Jasmonic acid in seed dormancy of Acer tataricum. Biochemie und Physiologie der Pflanzen 187(1): 1319.

Besseau, S. , J. Li , and E. T. Palva . 2012. WRKY54 and WRKY70 co-operate as negative regulators of leaf senescence in Arabidopsis thaliana. Journal of Experimental Botany 63: 26672679.

Bewlay, J. D. and M. Black . 1994. Seeds: Physiology of developmental and germination. 2nd edition, Plenum press, New York.

Bialecka, B. and J. Kepczynski . 2003. Endogenous ethylene and reversing methyl jasmonate inhibition of Amaranthus caudatus seed germination by benzyladenine or gibberellin. Plant Growth Regulation 41: 712.

Bonaventure, G. , S. Schuck , and I. T. Baldwin . 2011. Revealing complexity and specificity in the activation of lipase-mediated oxylipin biosynthesis: A specific role of the Nicotiana attenuata GLA1 lipase in the activation of jasmonic acid biosynthesis in leaves and roots. Plant Cell Environment 34: 15071520.

Boughton, A. J. , K. Hoover , and G. W. Felton . 2005. Methyl jasmonate application induces increased densities of glandular trichomes on tomato (Lycopersicon esculentum). Journal of Chemical Ecology 31:22112216.

Brash, A. R. 2009. Mechanistic aspects of CYP74 allene oxide synthases and related cytochrome P450 enzymes. Phytochemistry 70: 15221531.

Brash, A. R. , S. W. Baertschi , C. D. Ingram , et al. 1988. Isolation and characterization of natural allene oxides: Unstable intermediates in the metabolism of lipids hydroxides. Proceedings of the National Academy of Sciences of the United States of America 85: 33823386.

Browse, J. 2009a. Jasmonate passes muster: A receptor and targets for the defense hormone, Annual Review in Plant Biology 60: 183205.

Browse, J. 2009b. Jasmonate: Preventing the maize tassel from getting in touch with his feminine side. Science Signalling 2(59): 9.

Burns, J. K. , L. V. Pozo , C. R. Arias , et al. 2003. Coronatine and abscission in citrus. Journal of the American Society for Horticultural Science 128: 309315.

Cai, Q. , Z. Yuan , M. Chen , et al. 2014. Jasmonic acid regulates spikelet development in rice. Nature Communication 5: 3476.

Castillo, M. C. , C. Martnez , A. Buchala , et al. 2004. Gene-specific involvement of beta-oxidation in wound-activated responses in Arabidopsis. Plant Physiology 135: 8594.

Castro, G. , T. Kraus , and G. Abdala . 1999. Endogenous jasmonic acid and radial cell expansion in buds of potato tubers. Journal of Plant Physiology 155:706710.

Choudhary, S.P. , J. Q. Yu , K. Yamaguchi-Shinozaki , et al. 2012. Benefits of brassinosteroid crosstalk. Trends in Plant Science 17:594605.

Corbineau, F. , R. M. Rudnicki , and D. Come . 1988. The effects of methyl jasmonate on sunflower (Helianthus annuus L.) seed germination and seedling development. Plant Growth Regulation 7:157169.

Czerpak, R. , A. Piotrowska , and K. Szleska . 2006. Jasmonic acid affects changes in the growth and some components content in alga Chlorella vulgaris. Acta Physiologeiae Plantarum 28:195203.

Daletskaya, T. V. and G. Sembdner . 1989. Effect of jasmonic acid on germination of nondormant and dormant seeds. Fiziologija Rastenij 36: 11181123.

Dave, A. , M. L. Hernndez , Z. He , et al. 2011. 12-Oxo-phytodienoic acid accumulation during seed development represses seed germination in Arabidopsis. The Plant Cell 23:583599.

Demmig-Adams, B. and Adams, W. W. III. 2000. Photosynthesis: Harvesting sunlight safely. Nature 403: 371374.

Demole, E. , E. Lederer , and D. Mercier . 1962. Isolement et dtermination de la structure du jasmonate de mthyle, constituant odorant charactristique de lssence de jasmin. Helvetica Chimica Acta 45: 675685.

Ding, H. , J. Lai , Q. Wu , et al. 2016. Jasmonate complements the function of Arabidopsis lipoxygenase3 in salinity stress response. Plant Science 244: 17.

Edwards, G. E. and D. A. Walker . 1983. C3, C4: Mechanisms, and Cellular and Environmental Regulation of Photosynthesis. Blackwell, London.

Ewart, A. J. 1896. On assimilatory inhibition in plants. The Botanical Journal of the Linnean Society 31: 364461.

Farmaki, T. , M. Sanmartn , P. Jimnez , et al. 2007. Differential distribution of the lipoxygenase pathway enzymes within potato chloroplasts. Journal of Experimental Botany 58: 555568.

322 Feussner, I. and C. Wasternack . 2002. The lipoxygenase pathway. Annual Review of Plant Biology 53: 275297.

Feussner, I. , B. Hause , K. Vrs , et al. 1995. Jasmonate-induced lipoxygenase forms are localized in chloroplasts of barley leaves (Hordeum vulgare cv. Salome). The Plant Journal 7: 949957.

Fidelibus, M. W. , K. A. Cathline , and J. K. Burns . 2007. Potential abscission agents for raisin table and wine grapes. HortScience 42:16261630.

Fischer, C. and W. Holl . 1991. Food reserves in Scots pine (L.) I. Seasonal changes in the carbohydrate and fat reserves of pine needles. Tree 5: 187195.

Fonseca, S. , A. Chini , M. Hamberg , et al. 2009.7-iso-Jasmonoyl-L-isoleucine is the endogenous bioactive jasmonate. Nature Chemical Biology. 5:344 344.

Foyer, C. H. , J. Neukermans , G. Queval , et al. 2012. Harbinson Photosynthetic control of electron transport and the regulation of gene expression. Journal of Experimental Botany 63:16371661.

Foyer, C. H. and G. Noctor . 2005. Redox homeostasis and antioxidant signaling: A metabolic interface between stress perception and physiological responses. Plant Cell 17: 18661875.

Foyer, C. H. and S. Shigeoka . 2011. Understanding oxidative stress and antioxidant functions to enhance photosynthesis. Plant Physiology. 155: 93100.

Froehlich, J. E. , A. Itoh , and G. A. Howe . 2001. Tomato allene oxide synthase and fatty acid hydroperoxide lyase, two cytochrome P450s involved in oxylipin metabolism, are targeted to different membranes of chloroplast envelope. Plant Physiology 125: 306317.

Fukumoto, K. , K. Alamgir , Y. Yamashita , et al. 2013. Response of rice to insect elicitors and the role of OsJAR1 in wound and herbivory-induced JA-Ile accumulation. Journal of Integrative Plant Biology 55: 775784.

Gao, X. , X. Wang , Y. Lu , et al. 2004. Jasmonic acid is involved in the water stress induced betaine accumulation in pear leaves. Plant Cell Environment 27: 54975507.

Gasperini, D. , A. Chauvin , I. F. Acosta , et al. 2015. Axial and radial oxylipin transport. Plant Physiology 169: 22442254.

Geransayeh, M. , S. Sepahvand , V. Abdossi , et al. 2015. Effect of methyl jasmonate treatment on decay, post-harvest life and quality of Strawberry (Fragaria ananassa L. cv. Gaviota) fruit. International Journal of Current Science 15(E): 123131.

Gidda, S. , O. Miersch , A. Levitin , et al. 2003. Biochemical and molecular characterization of a hydroxyjasmonate sulfotransferase from Arabidopsis thaliana. Journal of Biological Chemistry 278: 1789517900.

Gill, S. S. , N. Tuteja. 2010. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiology and Biochemistry 48(12): 909930.

Goetz, S. , A. Hellwege, and I. Stenzel . 2012. Role of cis-12-oxo-phytodienoic acid in tomato embryo development. Plant Physiology 158: 17151727.

Gonzalez-Herranz, R. , K. A. Cathline , M. W. Fidelibus , et al. 2009. Potential of methyl jasmonate as a harvest aid for thompson seedless grapes: Concentration and time needed for consistent berry loosening. HortScience 44:13301333.

Grebner, W. , N. E. Stingl , A. Oenel , et al. 2013. Lipoxygenase6-dependent oxylipin synthesis in roots is required for abiotic and biotic stress resistance of Arabidopsis. Plant Physiology 161: 21592170.

Gu, X. C. , J. F. Chen , Y. Xiao , et al. 2012. Overexpression of allene oxide cyclase promoted tanshinone/phenolic acid production in Salvia miltiorrhiza. Plant Cell Reports 31: 22472259.

Gutierrez, L. , G. Mongelard , K. Flokova , et al. 2012. Auxin controls Arabidopsis adventitious root initiation by regulating jasmonic acid homeostasis. The Plant Cell. 24(6): 25152527.

Haga, K. and M. Iino . 2004. Phytochrome-mediated transcriptional up-regulation of ALLENE OXIDE SYNTHASE in rice seedlings. Plant and Cell Physiology 45: 119128.

Hanaka, A. , W. Maksymiec , and W. Bednarek . 2015. The effect of methyl jasmonate on selected physiological parameters of copper-treated Phaseolus coccineus plants. Plant Growth Regulation 77(2): 167177.

Hanik, N. , S. Gmez , M. Best , et al. 2010. Partitioning of new carbon as and sup1; and sup1; C in Nicotiana tabacum reveals insight into methyl jasmonate induced changes in metabolism. Journal of Chemical Ecology 36: 10581067.

Hartmond, U. , R. Yuan , J. K. Burns , et al. 2000. Citrus fruit abscission induced by methyl-jasmonate. Journal of the American Society for Horticultural Science 125(5): 547552.

He, Y. , H. Fukushige , D. F. Hildebrand , et al. 2002. Evidence supporting a role of jasmonic acid in Arabidopsis leaf senescence. Plant Physiology 128: 876884.

Heitz, T. , E. Smirnova , E. Widemann , et al. 2016. The rise and fall of jasmonate biological activities. In: Lipids in plant and algae development, Nakamura, Y. , Li-Beisson, Y. , eds. Cham: Springer International Publishing, 405426.

Hofmann, E. and S. Pollmann . 2008. Molecular mechanism of enzymatic allene oxide cyclization in plants. Plant Physiology and Biochemistry 46: 302308.

Hofmann, E. , P. Zerbe , and F. Schaller . 2006. The crystal structure of Arabidopsis thaliana all ene oxide cyclase: Insights into the oxylipin cyclization reaction. The Plant Cell 18: 32013217.

Hristova, V. A. and L. P. Popova . 2002. Treatment with methyl jasmonate alleviates the effects of paraquat on photosynthesis in barley plants. Photosynthetica 40: 567574.

Hu, J. , A. Baker , B. Bartel , et al. 2012. Plant peroxisomes: Biogenesis and function. The Plant Cell 24: 22792303.

Hughes, R. K. , S. De Domenico , and A. Santino . 2009. Plant cytochrome CYP74 family: Biochemical features, endocellular localisation, activation mechanism in plant defence and improvements for industrial applications. ChemBioChem 10: 11221133.

Ishiguro, S. , A. Kawai-Oda , and K. Ueda . 2001. The DEFECTIVE IN ANTHER DEHISCENCE1 gene encodes a novel phospholipase A1 catalyzing the initial step of jasmonic acid biosynthesis, which synchronizes pollen maturation, anther dehiscence, and flower opening in Arabidopsis. Plant Cell 13:21912209.

Ito, T. , K. H. Ng , T. S. Lim , et al. 2007. The homeotic protein AGAMOUS controls late stamen development by regulating a jasmonate biosynthetic gene in Arabidopsis. The Plant Cell 19: 35163529.

Jamalomidi, F. , J. Sarmad , and M. Jamalomidi . 2013. Changes caused by Methyl Jasmonate in Cocker 347- a cultivar of tobacco (Nicotine tabacum L.) under salinity stress. International Research Journal of Applied and Basic Sciences. 4(5): 11391145.

Jarvis, S. B. , M. A. Taylor , M. R. MacLeod , et al. 1996. Cloning and characterisation of the cDNA clones of three genes that are differentially expressed during dormancy-breakage in the seeds of Douglas fir (Pseudotsuga menziesii). Journal of Plant Physiology 147(5): 559566.

323 Jung, S. 2004. Effect of chlorophyll reduction in Arabidopsis thaliana by methyl jasmonate or norflurazon on antioxidant systems. Journal of Plant Physiology and Biochemistry 42: 231255.

Kangasjarvi, S. , J. Neukermans , S. Li , et al. 2012. Photosynthesis, photorespiration, and light signalling in defence responses. Journal of Experimental Botany 63:16191636.

Katsir, L. , A. L. Schilmiller , P. E. Staswick , et al. 2008. COI1 is a critical component of a receptor for jasmonate and the bacterial virulence factor coronatine. Proceedings of the National Academy of Sciences, USA 105: 71007105.

Kaur, H. , P. Sharma , and G. Sirhindi . 2013. Sugar accumulation and its regulation by jasmonic acid in Brassica napus L. under salt stress. Journal of Plant Physiology and Biochemistry 9:5364.

Kazemi, M. 2014. Effect of foliar application with salicylic acid and methyl jasmonate on growth, flowering, yield and fruit quality of tomato. Bulletin of Environment, Pharmacology and Life Sciences 3:154158.

Kender, W. J. , U. Hartmond , J. K. Burns , et al. 2001. Methyl jasmonate and CMN-pyrazole applied alone and in combination can cause mature orange abscission. Scientia Horticulturae 88:107120.

Kepczynski, J. and B. Bialecka . 1994. Stimulatory effect of ethephon, ACC, gibberellin A-3 and A-4+7 on germination of methyl jasmonate inhibited Amaranthus caudatus L. seeds. Plant Growth Regulation 14: 211216

Kim, J. 2014. Four shades of detachment: Regulation of floral organ abscission. Plant Signaling and Behaviour 9:e976154.

Knopf, R. R. , A. Feder , K. Mayer , et al. 2012. Rhomboid proteins in the chloroplast envelope affect the level of allene oxide synthase in Arabidopsis thaliana. The Plant Journal 72: 559571.

Kobayashi, H. , M. Yanaka , and T. M. Ikeda . 2010. Exogenous methyl jasmonate alters trichome density on leaf surfaces of Rhodes grass (Chloris gayana Kunth). Journal of Plant Growth Regulation 29:506511

Koda, Y. 1997. Possible involvement of jasmonates in various morphogenic events. Physiologia Plantarum 100: 639646.

Koeduka, T. , K. Ishizaki , C. M. Mwenda , et al. 2015. Biochemical characterization of allene oxide synthases from the liverwort Marchantia polymorpha and green microalgae Klebsormidium flaccidum provides insight into the evolutionary divergence of the plant CYP74 family. Planta 242: 11751186.

Kolomiets, M. V. , D. J. Hannapel , H. Chen. , et al. 2001. Lipoxygenase is involved in the control of potato tuber development. The Plant Cell 13(3): 613626.

Kombrink, E. 2012. Chemical and genetic exploration of jasmonate biosynthesis and signaling paths. Planta 236: 1351 1351.

Koo, A. J. , H. S. Chung , and Y. Kobayashi . 2006. Identification of a peroxisomal acyl-activating enzyme involved in the biosynthesis of jasmonic acid in Arabidopsis. Journal of Biological Chemistry 281: 3351133520.

Koo, A. J. and G. A. Howe . 2012. Catabolism and deactivation of the lipidderived hormone jasmonoyl-isoleucine. Frontiers in Plant Science 3: 19.

Krause, G. H. 1988. Photoinhibition of photosynthesis. an evaluation of damaging and protective mechanisms. Plant Physiology 74: 566574.

Kucera, B. , M. A. Cohn , G. Leubner-Metzger . 2005. Plant hormone interactions during seed dormancy release and germination. Seed Science Research 15:281307.

Larrieu, A. , A. Champion , J. Legrand , et al. 2015. A fluorescent hormone biosensor reveals the dynamics of jasmonate signalling in plants. Nature Communications 6: 6043.

Laudert, D. , F. Schaller , and E. W. Weiler . 2000. Transgenic Nicotiana tabacum and Arabidopsis thaliana plants overexpressing allene oxide synthase. Planta 211: 163165.

Le, D. T. , R. Nishiyama , Y. Watanabe , et al. 2012. Identification and expression analysis of cytokinin metabolic genes in soybean under normal and drought conditions in relation to cytokinin levels. PLoS One 7: 42411.

Lee, D. E. and K. Back . 2005. Ectopic expression of MAP kinase inhibits germination and seedling growth in transgenic rice. Plant Growth Regulation 45:251257.

Li, C. , A. L. Schilmiller , G. Liu , et al. 2005. Role of -oxidation in jasmonate biosynthesis and systemic wound signaling in tomato. The Plant Cell 17: 971986.

Li, W. , F. Zhou , B. Liu , et al. 2011. Comparative characterization, expression pattern and function analysis of the 12-oxo-phytodienoic acid reductase gene family in rice. Plant Cell Reports 30: 981995.

Li, X-R. , H. J. Li , L. Yuan , et al. 2014. Arabidopsis DAYU/ABERRANT PEROXISOME MORPHOLOGY9 is a key regulator of peroxisome biogenesis and plays critical roles during pollen maturation and germination in planta. The Plant Cell 26: 619635.

Lin, Y. T. , L. J. Chen , C. Herrfurth , et al. 2016. Reduced biosynthesis of digalactosyldiacylglycerol, a major chloroplast membrane lipid, leads to oxylipin overproduction and phloem cap lignification in Arabidopsis. The Plant Cell 28: 219232.

Linkies, A. G. and G. Leubner-Metzger. 2012. Beyond gibberellins and abscisic acid: How ethylene and jasmonates control seed germination. Plant Cell Reports 31: 253270.

Liu, X. , F. Li , J. Tang , et al. 2012. Activation of the jasmonic acid pathway by depletion of the hydroperoxide lyase OsHPL3 reveals crosstalk between the HPL and AOS branches of the oxylipin pathway in rice. PLoS One 7: e50089.

Long, S. P. , T. M. East , and N.R. Baker . 1983. Chilling damage to photosynthesis in young Zea mays. I. Effects of light and temperature variation on photosynthetic CO2 assimilation. Journal of Experimental Botany. 34, 177188.

Lorenzo, O. , J. M. Chico , and J. J. Sa . 2004. JASMONATE-INSENSITIVE1encodes a MYC transcription factor essential to discriminate between different jasmonate regulated defense responses in Arabidopsis. Plant Cell. 16(7):19381950.

Matsuki, T. , H. Tazaki , T. Fujimori , et al. 1992. The influences of jasmonic acid methyl-ester on microtubules in potato cells and formation of potato-tubers. Bioscience Biotechnology and Biochemistry 56 (8):13291330.

Maucher, H. , B. Hause , and I. Feussner . 2000. Allene oxide synthases of barley (Hordeum vulgare cv. Salome): Tissue specific regulation in seedling development. The Plant Journal 21: 199 199.

Meesters, C. , T. Mnig , J. Oeljeklaus , et al. 2014. A chemical inhibitor of jasmonate signaling targets JAR1 in Arabidopsis thaliana. Nature Chemical Biology 10: 830836.

Melis, A. 1999. Photosystem II damage and repair cycle in chloroplasts: What modulates the rate of photodamage in vivo? Trends in Plant Sciences 4:130135.

Melotto, M. , C. Mecey , Y. Niu , et al. 2008. A critical role of two positively charged amino acids in the Jas motif of Arabodopsis JAZ proteins in mediating coronatine- and jasmonoyl isoleucin e-dependent interactions with the COI1 F-box protein. The Plant Journal 55: 979988.

324 Meyer, A. , O. Miersch , and C. Biittner . 1984. Occurrence of the plant growth regulator jasmonic acid in plants. Journal of Plant Growth Regulation 3: 18.

Miersch, O. , J. Neumerkel , M. Dippe , et al. 2008. Hydroxylated jasmonates are commonly occurring metabolites of jasmonic acid and contribute to a partial switch-off in jasmonate signaling. New Phytologist 177: 114127.

Miersch, O. and C. Wasternack . 2000. Octadecanoid and jasmonate signaling in tomato (Lycopersicon esculentum Mill.) leaves: endogenous jasmonates do not induce jasmonate biosynthesis. Biological Chemistry 381: 715722.

Monte, I. , M. Hamberg , A. Chini , et al. 2014. Rational design of a ligand-based antagonist of jasmonate perception. Nature Chemical Biology 10: 671676.

Monzn, G. C. , M. Pinedo , L. Lamattina , et al. 2012. Sunflower root growth regulation: The role of jasmonic acid and its relation with auxins. Plant Growth Regulation 66(2): 129136.

Murata, N. , S. Takahashi , Y. Nishiyama . et al. 2007. Photoinhibition of photosystem II under environmental stress. Biochimica et Biophysica Acta 1767: 414421.

Nath, K. , A. Jajoo , R. S. Poudyal , et al. 2013. Towards a critical understanding of the photosystem II repair mechanism and its regulation during stress conditions. FEBS Letters 587: 33723381.

Nazarli, H. , A. Ahmadi , and J. Hadian . 2014. Salicylic acid and methyl jasmonate enhance drought tolerance in chamomile plants. Journal of HerbMed Pharmacology 3(2):8792.

Neumann, P. , F. Brodhun , K. Sauer , et al. 2012. Crystal structures of Physcomitrella patens AOC1 and AOC2: Insights into the enzyme mechanism and differences in substrate specificity. Plant Physiology 160: 12511266.

Nishiyama, Y. and N. Murata . 2014. Revised scheme for the mechanism of photoinhibition and its application to enhance the abiotic stress tolerance of the photosynthetic machinery. Applied Microbiology and Biotechnology 98: 87778796.

Nishiyama, Y. , S. I. Allakhverdiev , N. Murata , et al. 2006. A new paradigm for the action of reactive oxygen species in the photoinhibition of photosystem II. Biochimica et Biophysica Acta 1757: 742749.

Nishiyama, Y. , S. I. Allakhverdiev , H. Yamamoto , et al. 2004. Singlet oxygen inhibits the repair of photosystem II by suppressing the translation elongation of the D1 protein in Synechocystis sp. PCC 6803. Biochemistry 43: 1132111330.

Nishiyama, Y. , H. Yamamoto , S. I. Allakhverdiev , et al. 2001. Oxidative stress inhibits the repair of photodamage to the photosynthetic machinery. EMBO Journal 20: 55875594.

Niyogi, K. K. 2000. Safety valves for photosynthesis. Current Opinion in Plant Biology 3: 455460.

Noir, S. , M. Bmer , N. Takahashi , et al. 2013. Jasmonate controls leaf growth by repressing cell proliferation and the onset of endoreduplication while maintaining a potential stand-by mode. Plant Physiology 161:19301951.

Nojavan-Asghari, M. and K. Ishizawa . 1998. Inhibitory effects of methyl jasmonate on the germination and ethylene production in cocklebur seeds. Journal of Plant Growth Regulation 17:1318.

Norastehnia, A. , R. H. Sajedi , and M. Nojavan-Asghari . 2007. Inhibitory effects of methyl jasmonate on seed germination in maize (Zea Mays): Effect on -amylase activity and ethylene production. General and Applied Plant Physiology 33: 1323.

Oh, E. , H. Kang , S. Yamaguchi , et al. 2009. Genome-wide analysis of genes targeted by PHYTOCHROME INTERACTING FACTOR 3-LIKE5 during seed germination in Arabidopsis. The Plant Cell 21:403419.

Oh, Y. , I. T. Baldwin , and I. Galis . 2013. A Jasmonate ZIM-Domain protein NaJAZd regulates floral jasmonic acid levels and counteracts flower abscission in Nicotiana attenuata plants. PLoS One 8(2): 111.

Osakabe, Y. , K. Yamaguchi-Shinozaki , K. Shinozaki , et al. 2014. ABA control of plant macroelement membrane transport systems in response to water deficit and high salinity. New Phytologist 202:3549.

Osmond, C. B. 1994. What is photoinhibition? Some insights from comparisons of sun and shade plants. In: Photoinhibition of Photosynthesis: From Molecular Mechanisms to the Field, Baker, N.R. , Bowyer, J.R. eds., pp. 124. Bios Scientific Publishers, Oxford.

Otto, M. , C. Naumann , W. Brandt , et al. 2016. Activity regulation by heteromerization of arabidopsis allene oxide cyclase family members. Plants 5: 3.

Ozalvo, R. , J. Cabrera , C. Escobar , et al. 2014. Two closely related members of Arabidopsis 13-lipoxygenases (13-LOXs), LOX3 and LOX4, reveal distinct functions in response to plantparasitic nematode infection. Molecular Plant Pathology 15: 319332.

Pak, H. , Y. Guo , M. Chen , et al. 2009. The effect of exogenous methyl jasmonate on the flowering time, floral organ morphology, and transcript levels of a group of genes implicated in the development of oilseed rape flowers (Brassica napus L.). Planta 231: 7991.

Patil, R. A. , S. K. Lenka , J. Normanly , et al. 2014. Methyl jasmonate represses growth and affects cell cycle progression in cultured taxus cells. Plant Cell Reports. 33(9):14791492.

Pauwels, L. , K. Morreel , E. De Witte , et al. 2008. Mapping methyl jasmonate-mediated transcriptional reprogramming of metabolism and cell cycle progression in cultured Arabidopsis cells. Proceedings of the National Academy of Sciences of the USA 105: 13801385.

Pret, B. , A. Larrieu , and M. J. Bennett . 2009. Lateral root emergence: A difficult birth. Journal of Experimental Botany 60:36373643

Petricka, J. J. , C. M. Winter , and P. N. Benfey . 2012. Control of Arabidopsis root development. Annual Review of Plant Biology. 63:563590.

Pfannschmidt, T. 2003. Chloroplast redox signals: how photosynthesis con- trols its own genes. Trends in Plant Science 8: 3341.

Pfndel, E. E. and W. Bilger . 1994. Regulation and possible function of the violaxanthin cycle. Photosynthesis Research 42: 89109.

Poonam, S. , H. Kaur , and S. Geetika . 2013. Effect of Jasmonic acid on photosynthetic pigments and stress markers in Cajanus cajan (L.) Millsp. seedlings under copper stress. American Journal of Plant Sciences 4:817823.

Powles, S. B. 1984. Photoinhibition of photosynthesis induced by visible light. Annual Review of Plant Physiology 35: 1544.

Powles, S. B. , J. A. Berry , and O. Bjorkman . 1983. Interaction between light and chilling temperature on the inhibition of photosynthesis in chilling-sensitive plants. Plant, Cell and Environment 6: 117123.

Preston, C. A. , H. Betts , and I. T. Baldwin . 2002. Methyl jasmonate as an allelopathic agent: Sagebrush inhibits germination of a neighboring tobacco, Nicotiana attenuata. Journal of Chemical Ecology 28: 23432369.

325 Puranik, S. , P. P. Sahu , P. S. Srivastava , et al. 2012. NAC proteins: Regulation and role in stress tolerance. Trends in Plant Sciences 17: 369381.

Qi, T. , S. Song , Q. Ren , et al. 2011. The jasmonate-ZIM-domain proteins interact with the WD-repeat/bHLH/MYB complexes to regulate jasmonate-mediated anthocyanin accumulation and trichome initiation in Arabidopsis thaliana. Plant Cell 23: 17951814.

Rabinowitch, E. I. 1951. Photosynthesis. Volume II, Part 1. Inter-science Publishers, New York.

Ranjan, R. and S. Lewak . 1992. Jasmonic acid promotes germination and lipase activity in nonstratified apple embryos. Physiologia Plantarum 86: 335339.

Richmond, T. and A. Bleecker . 1999. A defect in -oxidation causes abnormal inflorescence development in Arabidopsis. The Plant Cell 11: 19111923.

Riemann, M. , K. Haga , T. Shimizu , et al. 2013. Identification of rice allene oxide cyclase mutants and the function of jasmonate for defence against Magnaporthe oryzae. The Plant Journal 74: 226238.

Rochaix, J. D. 2011. Regulation of photosynthetic electron transport. Biochimica et Biophysica Acta 1807: 375383.

Samet, A. E. , K. Piri , M. Kayhanfar , et al. 2012. Influence of jasmonic acids, yeast extract and salicylic acid on gr owth and accumulation of hyosciamine and scopolamine in hairy root cultures of Atropa belladonna L. International Journal of Agriculture: Research and Review 2(4): 403409.

Saniewski, M. , M. Horbowicz , J. Puchalski , et al. 2003. Methyl jasmonate stimulates the formation and accumulation of anthocyanins in Kalanchoe blossfeldiana. Acta Physiologie Plantarum 25: 143149.

Sassenrath, G. F. , D. R. Ort , and A. R. Jr. Portis . 1990. Impaired reductive activation of stromal bisphosphatases in tomato leaves following low-temperature exposure at high light. Archives of Biochemistry and Biophysics 282: 302308.

Savchenko, T. , D. Yanykin , A. Khorobrykh , et al. 2017. The hydroperoxide lyase branch of the oxylipin pathway protects against photoinhibition of photosynthesis. Planta 245: 11791192.

Schaller, A. and A. Stintzi . 2009. Enzymes in jasmonate biosynthesisStructure, function, regulation. Phytochemistry 70: 1532 1532.

Schaller, F. , P. Zerbe , S. Reinbothe , et al. 2008. The allene oxide cyclase family of Arabidopsis thaliana: Localization and cyclization. FEBS Journal 275: 24282441.

Schilmiller, A. L. , A. J. K. Koo , and G. A. Howe . 2007. Functional diversification of acyl-coenzyme A oxidases in jasmonic acid biosynthesis and action. Plant Physiology 143: 812824.

Schmutz, J. , S. B. Cannon , J. Schlueter , et al. 2010. Genome sequence of the palaeopolyploid soybean. Nature 463:178183.

Schneider, K. , L. Kienow , E. Schmelzer , et al. 2005. A new type of peroxisomal acyl-coenzyme A synthetase from Arabidopsis thaliana has the catalytic capacity to activate biosynthetic precursors of jasmonic acid. Journal of Biological Chemistry 280: 1396213972.

Scholz, S. S. , M. Reichelt , W. Boland. 2015. Additional evidence against jasmonate-induced jasmonate induction hypothesis. Plant Science 239: 914.

Schuck, S. , M. Kallenbach , I. T. Baldwin , et al. 2014. Bonaventure G. The Nicotiana attenuata GLA1 lipase controls the accumulation of Phytophthora parasitica-induced oxylipins and defensive secondary metabolites. Plant Cell Environment 37(7): 17031715.

Seltmann, M. A. , N. E. Stingl , J. K. Lautenschlaeger , et al. 2010. Differential impact of lipoxygenase 2 and jasmonates on natural and stress-induced senescence in Arabidopsis. Plant Physiology 152: 19401950.

Sharkey, T. D. 1985. Photosynthesis in intact leaves of C3 plants: Physics, physiology and rate limitations. Botanical Review 51: 53105.

Sheard, L. B. , X. Tan , H. Mao , et al. 2010. Jasmonate perception by inositol-phosphate-potentiated COI1JAZ co-receptor. Nature 468: 400405.

Sheteawi, S. 2007. Improving growth and yield of salt-stressed soybean by exogenous application of jasmonic acid and ascobin. International Journal of Agriculture and Biology 9(3): 473478.

Shibaoka, H. 1994. Plant hormone-induced changes in the orientation of cortical microtubules: Alteration of the cross-linking between microtubules and the plasma membrane. Annual Review Plant Physiology 45: 527544

Shih, C. F. , W. H. Hsu , Y. J. Peng , et al. 2014. The NAC-like gene ANTHER INDEHISCENCE FACTOR acts as a repressor that controls anther dehiscence by regulating genes in the jasmonate biosynthesis pathway in Arabidopsis. Journal of Experimental Botany 65: 621 621.

Sirhindi, G. , M. A. Mir , E. F. Abd-Allah , et al. 2016. Jasmonic acid modulates the physio-biochemical attributes, antioxidant enzyme activity, and gene expression in Glycine max under nickel toxicity. Frontiers in Plant Science 7: 591.

Sirhindi, G. , P. Sharma , A. Singh , et al. 2015. Alteration in photosynthetic pigments, osmolytes and antioxidants in imparting copper stress tolerance by exogenous jasmonic acid treatment in Cajanus cajan. International Journal of Plant Physiology and Biochemistry 7: 3039.

Skrzypek, E. , K. Miyamoto , M. Saniewski , et al. 2005. Jasmonates are essential factors inducing gummosis in tulips: Mode of action of jasmonates focusing on sugar metabolism. Journal of Plant Physiology 162: 495505.

Sohn, H. B. , H. Y. Lee , J. S. Seo , et al. 2011. Overexpression of jasmonic acid carboxyl methyltransferase increases tuber yield and size in transgenic potato. Plant Biotechnology Reports 5(1): 2734.

Sorial, M. E. and A. A. Gendy . 2010. Response of sweet basil to jasmonic acid application in relation to different water supplies. Bioscience Research 7: 3947.

Spetea, C. , E. Rintamki , B. Schoefs , et al. 2014. Changing the light environment: Chloroplast signalling and response mechanisms. Philosophical transactions of the Royal Society of London. Series B, Biological sciences Royal Society 369: 20130220.

Springer, A. , Kang C. , S. Rustgi , et al. 2016. Programmed chloroplast destruction during leaf senescence involves 13-lipoxygenase (13-LOX). Proceedings of the National Academy of Sciences, USA 113: 33833388.

Staswick, P. E. and I. Tiryaki . 2004. The oxylipin signal jasmonic acid is activated by an enzyme that conjugates it to isoleucine in Arabidopsis. The Plant Cell 16: 21172127.

Stenzel, I. , B. Hause , H. Maucher , et al. 2003. Allene oxide cyclase dependence of the wound response and vascular bundlespecific generation of jasmonates in tomatoamplification in wound signaling. The Plant Journal 33: 577589.

326 Stenzel, I. , M. Otto , and C. Delker . 2012. Allene oxide cyclase (AOC) gene family members of Arabidopsis thaliana: Tissue- and organ-specific promoter activities and in vivo heteromerization. Journal of Experimental Botany 63: 6125 6125.

Stumpe, M. , C. Gbel , and B. Faltin . 2010. The moss Physcomitrella patens contains c yclopentenones but no jasmonates: Mutations in allene oxide cyclase lead to reduced fertility and altered sporophyte morphology. New Phytologists 188:740749.

Suza, W. P. , M. L. Rowe , and M. Hamberg . 2010. A tomato enzyme synthesizes (+)-7-iso-jasmonoyl-l-isoleucine in wounded leaves. Planta 231:717728.

Svyatyna, K. , Jikumaru. Y. , R. Brendel , et al. 2014. Light induces jasmonate isoleucine conjugation via OsJAR1-dependent and -independent pathways in rice. Plant, Cell and Environment 37:827839.

Swiatek, A. , A. Azmi , E. Witters , et al. 2003. Stress messengers jasmonic acid and abscisic acid negatively regulate plant cell cycle. Bulgarian Journal of Plant Physiology 29: 172178.

Swiatek, A. , M. Lenjou , D. Van Bockstaele , et al. 2002. Differential effect of jasmonic acid and abscisic acid on cell cycle progression in tobacco BY-2 cells. Plant Physiology 128:201211.

Takahashi, K. , K. Fujino., Y. Kikuta , et al. 1994. Expansion of potato cells.

Takahashi, S. and N. Murata . 2008. How do environmental stresses accelerate photoinhibition? Trends in Plant Science 13:178182.

Takahashi, T. , A. Gasch , N. Nishizawa , et al. 1995. The DIMINUTO gene of Arabidopsis is involved in regulating cell elongation. Genes and Development 9:97107.

Tani, T. , H. Sobajima , K. Okada , et al. 2008. Identification of the OsOPR7 gene encoding 12-oxophytodienoate reductase involved in the biosynthesis of jasmonic acid in rice. Planta 227:517526.

Theodoulou, F. L. , K. Job , S. P. Slocombe , et al. 2005. Jasmonic acid levels are reduced in COMATOSE ATP-binding cassette transporter mutants. Implications for transport of jasmonate precursors into peroxisomes. Plant Physiology 137: 835840.

Thines, B. , L. Katsir , M. Melotto , et al. 2007. JAZ repressor proteins are targets of the SCF(COI1) complex during jasmonate signalling. Nature 448:661665.

Tikkanen, M. , M. Grieco , E. Aro , et al. 2011. Novel insights into plant light-harvesting complex II phosphorylation and state transitions. Trends in Plant Sciences 16:126131.

Ubeda-Toms, S. , G. T. S. Beemster , and M. J. Bennett . 2012. Hormonal regulation of root growth: Integrating local activities into global behaviour. Trends in Plant Science 17(6):326331.

Ueda, J. and M. Saniewski . 2006. Methyl jasmonate-induced stimulation of chlorophyll formation in the basal part of tulip bulbs kept under natural light conditions. Journal of Fruit and Ornamental Plant Research 14:199210.

Van Schie, C. C. N. , M. A. Haring , and R. C. Schuurink . 2007. Tomato linalool synthase is induced in trichomes by jasmonic acid. Plant Molecular Biology 94: 251263.

Vick, B. A. and D. C. Zimmerman . 1983. The biosynthesis of jasmonic acid: a physiological role for plant lipoxygenase. Biochem Biophys Res Commun. 111(2):470477.

Wang, J. , J. Qian , L. Yao, et al. 2015. Enhanced production of flavonoids by methyl jasmonate elicitation in cell suspension culture of Hypericum perforatum. Bioresources and Bioprocessing 2(1):15.

Wang, L. , X. Yang , Z. Ren , et al. 2014. Alleviation of photosynthetic inhibition in copper-stressed tomatoes through rebalance of ion content by exogenous nitric oxide. Turkish Journal of Botany 38:113.

War, A. R. , B. Hussain , and H. C. Sharma . 2013. Induced resistance in groundnut by jasmonic acid and salicylic acid through alteration of trichome density and oviposition by Helicoverpa armigera (Lepidoptera: Noctuidae). AoB Plants 16.

Wasternack, C. 2007. Jasmonates: An update on biosynthesis, signal transduction and action in plant stress response, growth and development. Annals of Botany 100:681697.

Wasternack, C. 2014. Jasmonates in plant growth and stress responses. In: Phytohormones: A Window to Metabolism, Signaling and Biotechnological Applications, Tran, L. S. , Pal, S. , eds., pp. 221263. Springer, New York.

Wasternack, C. and B. Hause . 2002. Jasmonates and octadecanoidsSignals in plant stress response and development. In: Progress in Nucleic Acid Research and Molecular Biology, Moldave, K. , ed., pp. 165222. Academic Press, New York.
Wasternack, C. and B. Hause . 2013. Jasmonates: Biosynthesis, perception, signal transduction and action in plant stress response, growth and development. Annals of Botany 111(6):10211058.
Wasternack, C. and E. Kombrink . 2010. Jasmonates: Structural requirements for lipid-derived signals active in plant stress responses and development. ACS Chemical Biology 5:6377.
Wasternack, C. and M. Strnad . 2016. Jasmonate signaling in plant stress responses and developmentactive and inactive compounds. New Biotechnology 33:604613.
Westfall, C. S. , A. M. Muehler , and J. M. Jez . 2013. Enzyme action in the regulation of plant hormone responses. Journal of Biological Chemistry 288: 1930419311.
Westfall, C. S. , C. Zubieta , J. Herrmann , et al. 2012. Structural basis for prereceptor modulation of plant hormones by GH3 proteins. Science 336:17081711.
Wiszniewski, A. A. , J. D. Bussell , R. L. Long , et al. 2014. Knockout of the two evolutionarily conserved peroxisomal 3-ketoacyl-CoA thiolases in Arabidopsis recapitulates the abnormal inflorescence meristem 1 phenotype. Journal of Experimental Botany 65:67236733.
Wu, M. , A. Neilson , A. L. Swift , et al. 2007. Multiparameter metabolic analysis reveals a close link between attenuated mitochondrial bioenergetic function and enhanced glycolysis dependency in human tumor cells. American Journal Physiology and Cell Physiology 292:C125C136.
Xiao, Y. , Y. Chen , T. Charnikhova , et al. 2014. OsJAR1 is required for JA-regulated floret opening and anther dehiscence in rice. Plant Molecular Biology 86:1933.
Yamamoto Y. , J. Ohshika , and T. Takahashi . 2015. Functional analysis of allene oxide cyclase, MpAOC, in the liverwort Marchantia polymorpha. Phytochemistry 116:4856.
Yan, J. , S. Li , M. Gu , et al. 2016. Endogenous bioactive jasmonate is composed of a set of (+)-7-iso-JA amino acid conjugates. Plant Physiology 172(4):21542164. DOI:10.1104/pp.16.00906.
Yan, J. , Zhang. C. , M. Gu , et al. 2009. The Arabidopsis CORONATINE INSENSITIVE1 protein is a jasmonate receptor. The Plant Cell 21: 22202236.
Yan, L. , Q. Zhai , J. Wei , et al. 2013. Role of tomato lipoxygenase D in wound-induced jasmonate biosynthesis and plant immunity to insect herbivores. PLoS Genetics 9:e1003964.
327 Yang, D. L. , J. Yao , C. S. Mei , et al. 2012. Plant hormone jasmonate prioritizes defense over growth by interfering with gibberellin signaling cascade. Proceedings of the National Academy of Sciences of the USA 109:E1192E1200.
Yldz, K. , C. Yazc , and F. Muradolu . 2007. Effect of jasmonic acid on germination dormant and nondormant apple seeds. Asian Journal of Chemistry 19 (2): 10981102.
Yoeun, S. , R. Rakwal , and O. Han . 2013. Dual positional substrate specificity of rice allene oxide synthase-1: Insight into mechanism of inhibition by type II ligand imidazole. BMB Reports 46:151156.
Yoshida, Y. , R. Sano , T. Wada , et al. 2009. Jasmonic acid control of GLABRA3 links inducible defense and trichome patterning in Arabidopsis. Development 136:10391048.
Ytterberg, A. J. , J. B. Peltier , and K. J. van Wijk . 2006. Protein profiling of plastoglobules in chloroplasts and chromoplasts. A surprising site for differential accumulation of metabolic enzymes. Plant Physiology 140: 984997.
Yuan, Z. and D. Zhang . 2015. Roles of jasmonate signalling in plant inflorescence and flower development. Current Opinion in Plant Biology 27:4451.
Zalewski, K. , B. Nitkiewicz , L. B. Lahuta , et al. 2010. Effect of jasmonic acid-methyl ester on the composition of carbohydrates and germination of yellow lupine (Lupinus luteus L.) seeds. Journal of Plant Physiology 167(12):967973.
Zhang, Y. and J. G. Turner . 2008. Wound-induced endogenous jasmonates stunt plant growth by inhibiting mitosis. PLos OnE 3:19.
Zhao, Y. , W. Dong , N. Zhang , et al. 2014. A wheat allene oxide cyclase gene enhances salinity tolerance via jasmonate signaling. Plant Physiology 164:10681076.
Zheng, H. , X. Pan , Y. Deng , et al. 2016. AtOPR3 specifically inhibits primary root growth in Arabidopsis under phosphate deficiency. Scientific Reports 6:24778.

Current Scenario of NO (S-Nitrosylation) Signaling in Cold Stress

Abat JK , Deswal R. Differential modulation of S-nitrosoproteome of Brassica juncea by low temperature: Change in S-nitrosylation of Rubisco is responsible for the inactivation of its carboxylase activity. Proteomics 2009a;9(18):43684380.
Abat JK , Deswal R. Post translational modifications of proteins by nitric oxidea new tool for metabolome regulation. In: Hayat S , Mori M , Pichtel J , Ahmad A , editors. Nitric Oxide in Plant Physiology. Germany:Wiley-VCH; 2009b, 189 189.
Airaki M , Leterrier M , Mateos RM , Valderrama R , Chaki M , Barroso JB , et al. Metabolism of reactive oxygen species and reactive nitrogen species in pepper (Capsicum annuum L.) plants under low temperature stress. Plant Cell Environ. 2012;35(2):281295.
Airaki M , Snchez-Moreno L , Leterrier M , Barroso JB , Palma JM , Corpas F.J. Detection and quantification of S-nitrosoglutathione (GSNO) in pepper (Capsicum annuum L.) plant organs by LC-ES/MS. Plant Cell Physiol. 2011;52(11):20062015.
Antoniou C , Savvides A , Christou A , Fotopoulos V. Unravelling chemical priming machinery in plants: The role of reactive oxygennitrogensulfur species in abiotic stress tolerance enhancement. Curr. Opin. Plant Biol. 2016;33:101107.
Barroso JB , Corpas FJ , Carreras A , Rodrguez-Serrano M , Esteban FJ , Fernndez-Ocaa A , et al. Localization of S-nitrosoglutathione and expression of S-nitrosoglutathione reductase in pea plants under cadmium stress. J. Exp. Bot. 2006;57(8):17851793.
Baudouin E. The language of nitric oxide signalling. Plant Biol. 2011;13(2):233242.
Bavita A , Shashi B , Navtej S.B. Nitric oxide alleviates oxidative damage induced by high temperature stress in wheat. Indian J. Exp. Biol. 2012;50:372378.
Benhar M , Forrester MT , Hess DT , Stamler JS . Regulated protein denitrosylation by cytosolic and mitochondrial thioredoxins. Science 2008;320:10501055.
Benhar M , Forrester MT , Stamler J.S. Protein denitrosylation: Enzymatic mechanisms and cellular functions. Nat. Rev. Mol. Cell Biol. 2009;10:112.
Benhar M , Thompson JW , Moseley MA , Stamler J.S. Identification of S-nitrosylated targets of thioredoxin using a quantitative proteomics approach. Biochemistry 2010;49(32):69636969.
Besson-Bard A , Courtois C , Gauthier A , Dahan J , Dobrowolska G , Jeandroz S , et al. Nitric oxide in plants: Production and cross-talk with Ca2+ signaling. Mol. Plant 2008;1(2):218228.
Bethke P.C. Apoplastic synthesis of nitric oxide by plant tissues. Plant Cell 2004;16(2):332341.

Birkenmeier G , Stegemann C , Hoffmann R , Gnther R , Huse K , Birkemeyer C. Posttranslational modification of human glyoxalase 1 indicates redox-dependent regulation. PLoS One 2010;5(4):e10399.

Bita CE , Gerats T. Plant tolerance to high temperature in a changing environment: Scientific fundamentals and production of heat stress-tolerant crops. Front. Plant Sci. 2013;4:118.

Bowler C , Slooten L , Vandenbranden S , De Rycke R , Botterman J , Sybesma C , et al. Manganese superoxide dismutase can reduce cellular damage mediated by oxygen radicals in transgenic plants. EMBO J. 1991;10(7):17231732.

Broniowska KA , Hogg N. The chemical biology of S-nitrosothiols. Antioxid. Redox Signal. 2012;17(7): 969980

Cantrel C , Vazquez T , Puyaubert J , Rez N , Lesch M , Kaiser WM , et al. Nitric oxide participates in cold-responsive phosphosphingolipid formation and gene expression in Arabidopsis thaliana. New Phytol. 2011;189(2):415427.

Carver J , Doctor A , Gaston B. S-Nitrosothiol formation. Methods Enzymol. 2005;396(5):95105.

Chae HB , Moon JC , Shin MR , Chi YH , Jung YJ , Lee SY , et al. Thioredoxin reductase type C (NTRC) orchestrates enhanced thermotolerance to Arabidopsis by its redox-dependent holdase chaperone function. Mol. Plant 2013;6(2):323336.

Chaki M , Valderrama R , Fernndez-Ocaa AM , Carreras A , Gmez-Rodrguez MV , Pedrajas JR , et al. Mechanical wounding induces a nitrosative stress by down-regulation of GSNO reductase and an increase in S-nitrosothiols in sunflower (Helianthus annuus) seedlings. J. Exp. Bot. 2011;62(6):18031813..

Cheng T , Chen J , Ef AA , Wang P , Wang G , Hu X , et al. Quantitative proteomics analysis reveals that S-nitrosoglutathione reductase (GSNOR) and nitric oxide signaling enhance poplar defense against chilling stress. Planta 2015;242(6):13611390.

Choudhury FK , Rivero RM , Blumwald E , Mittler R. Reactive oxygen species, abiotic stress and stress combination. Plant J. 2017;90(5):856867.

Cooney RV , Harwood PJ , Custer LJ , Franke A.A. Light-mediated conversion of nitrogen dioxide to nitric oxide by carotenoids. Environ. Health Perspect. 1994;102(5):460462.

Corpas FJ , Barroso JB , Carreras A , Quirs M , Len AM , Romero-Puertas MC , et al. Cellular and subcellular localization of endogenous nitric oxide in young and senescent pea plants. Plant Physiol. 2004;136(1):27222733.

Corpas FJ , Chaki M , Fernndez-Ocaa A , Valderrama R , Palma JM , Carreras A , et al. Metabolism of reactive nitrogen species in pea plants under abiotic stress conditions. Plant Cell Physiol. 2008;49(11):17111722.

Corpas FJ , Hayashi M , Mano S , Nishimura M , Barroso J.B. Peroxisomes are required for in vivo nitric oxide accumulation in the cytosol following salinity stress of Arabidopsis plants. Plant Physiol. 2009;151(4):20832094.

Dai C , Wang M.H. Isolation and characterization of thioredoxin and NADPH-dependent thioredoxin reductase from tomato (Solanum lycopersicum). BMB Rep. 2011;44(10):692697.

336 Fancy NN , Bahlmann AK , Loake G.J. Nitric oxide function in plant abiotic stress. Plant Cell Environ. 2017;40(4):462472.

Gibbs DJ , Md Isa N , Movahedi M , Lozano-Juste J , Mendiondo GM , Berckhan S , et al. Nitric oxide sensing in plants is mediated by proteolytic control of Group VII ERF transcription factors. Mol. Cell 2014;53(3):369379.

Gill SS , Tuteja N. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol. Biochem. 2010;48(12):909930.

Godber BLJ , Doel JJ , Sapkota GP , Blake DR , Stevens CR , Eisenthal R , et al. Reduction of nitrite to nitric oxide catalyzed by xanthine oxidoreductase. J. Biol. Chem. 2000;275(11):77577763.

Gupta KJ , Fernie AR , Kaiser WM , van Dongen J.T. On the origins of nitric oxide. Trends Plant Sci. 2011;16(3):160168.

Hara M , Harazaki A , Tabata K. Administration of isothiocyanates enhances heat tolerance in Arabidopsis thaliana. Plant Growth Regul. 2013;69(1):7177.

Hara M , Yatsuzuka Y , Tabata K , Kuboi T. Exogenously applied isothiocyanates enhance glutathione S-transferase expression in Arabidopsis but act as herbicides at higher concentrations. J. Plant Physiol. 2010;167(8):643649.

Hashemy SI , Holmgren A. Regulation of the catalytic activity and structure of human thioredoxin 1 via oxidation and S-nitrosylation of cysteine residues. J. Biol. Chem. 2008;283(32):2189021898.

Holtgrefe S , Gohlke J , Starmann J , Druce S , Klocke S , Altmann B , et al. Regulation of plant cytosolic glyceraldehyde 3-phosphate dehydrogenase isoforms by thiol modifications. Physiol. Plant. 2008;133(2):211228.

Hooper AB , Terry K.R. Hydroxylamine oxidoreductase of Nitrosomonas. Production of nitric oxide from hydroxylamine. BBA Enzymol. 1979;571(1):1220.

Jaspers P , Kangasjrvi J. Reactive oxygen species in abiotic stress signaling. Physiol. Plant. 2010;138(4):405413.

Kashyap P , Sehrawat A , Deswal R. Nitric oxide modulates Lycopersicon esculentum C-repeat binding factor 1 (LeCBF1) transcriptionally as well as post-translationally by nitrosylation. Plant Physiol. Biochem. 2015;96:115123.

Khokon MAR , Jahan MS , Rahman T , Hossain MA , Muroyama D , Minami I , et al. Allyl isothiocyanate (AITC) induces stomatal closure in Arabidopsis. Plant Cell Environ. 2011;34(11):19001906.

Kneeshaw S , Gelineau S , Tada Y , Loake GJ , Spoel S.H. Selective protein denitrosylation activity of thioredoxin-h5 modulates plant immunity. Mol. Cell 2014;56(1):153162.

Korithoski B , Lvesque CM , Cvitkovitch D.G. Involvement of the detoxifying enzyme lactoylglutathione lyase in Streptococcus mutans aciduricity. J. Bacteriol. 2007;189(21):75867592.

Kovacs I , Lindermayr C. Nitric oxide-based protein modification: Formation and site-specificity of protein S-nitrosylation. Front. Plant Sci. 2013;4:110.

Lee U , Wie C , Fernandez BO , Feelisch M , Vierling E. Modulation of nitrosative stress by S-nitrosoglutathione reductase is critical for thermotolerance and plant growth in Arabidopsis. Plant Cell 2008;20(3):786802.

Lima B , Lam GKW , Xie L , Diesen DL , Villamizar N , Nienaber J , et al. Endogenous S-nitrosothiols protect against myocardial injury. PNAS 2009;106(15):62976302.

Lindermayr C , Saalbach G , Durner J. Proteomic identification of S-nitrosylated proteins. Plant Physiol. 2005;137:921930.

Liu Y , Jiang H , Zhao Z , An L. Nitric oxide synthase like activity-dependent nitric oxide production protects against chilling-induced oxidative damage in Chorispora bungeana suspension cultured cells. Plant Physiol. Biochem. 2010;48(12):936944.

Martnez-Ballesta MDC , Moreno DA , Carvajal M. The physiological importance of glucosinolates on plant response to abiotic stress in Brassica. Int. J. Mol. Sci. 2013;14(6):1160711625.

Meister A. Glutathione metabolism and its selective modification. J. Biol. Chem. 1988;263(33):1720517208.

Mitsumoto A , Kim KR , Oshima G , Kunimoto M , Okawa K , Iwamatsu A , et al. Glyoxalase I is a novel nitric-oxide-responsive protein. Biochem. J. 1999;344:837844.

Mitsumoto A , Kim KR , Oshima G , Kunimoto M , Okawa K , Iwamatsu A , et al. Nitric oxide inactivates glyoxalase I in cooperation with glutathione. J. Biochem. 2000;128(4):647654.

Moon JC , Lee S , Shin SY , Chae HB , Jung YJ , Jung HS , et al. Overexpression of Arabidopsis NADPH-dependent thioredoxin reductase C (AtNTRC) confers freezing and cold shock tolerance to plants. Biochem. Biophys. Res. Commun. 2015;463(4):12251229.

Moroney JV , Bartlett SG , Samuelsson G. Carbonic anhydrases in plants and algae: Invited review. Plant Cell Environ. 2001;24(2):141153.

Neill S , Bright J , Desikan R , Hancock J , Harrison J , Wilson I. Nitric oxide evolution and perception. J. Exp. Bot. 2008;59(1):2535.
Neill SJ , Desikan R , Clarke A , Hurst RD , Hancock JT , Lane C , et al. Hydrogen peroxide and nitric oxide as signalling molecules in plants. J. Exp. Bot. 2002;53(372):12371247.
Neill SJ , Desikan R , Hancock J.T. Nitric oxide signalling in plants. Bot. Rev. 2003;159:1135.
Noctor G , Foyer C.H. Ascorbate and glutathione: Keeping active oxygen under control. Annu. Rev. Plant Biol. 1998;49(1):249279.
Puyaubert J , Fares A , Rz N , Peltier J , Baudouin E. Identification of endogenously S-nitrosylated proteins in Arabidopsis plantlets: Effect of cold stress on cysteine nitrosylation level. Plant Sci. 2014;215216:1501 56.
Qiao W , Li C , Fan L.M. Cross-talk between nitric oxide and hydrogen peroxide in plant responses to abiotic stresses. Environ. Exp. Bot. 2014;100:8493.
Radi R. Nitric oxide, oxidants, and protein tyrosine nitration. Proc. Natl. Acad. Sci. USA 2004;101(12):40034008.
Reichheld JP , Meyer E , Khafif M , Bonnard G , Meyer Y. AtNTRB is the major mitochondrial thioredoxin reductase in Arabidopsis thaliana. FEBS Lett. 2005;579(2):337342.
Romero-Puertas MC , Rodrguez-Serrano M , Sandalio LM. Protein S-nitrosylation in plants under abiotic stress: An overview. Front. Plant Sci. 2013;4:16.
Sakamoto A , Ueda M , Morikawa H. Arabidopsis glutathione-dependent formaldehyde dehydrogenase is an S-nitrosoglutathione reductase. FEBS Lett. 2002;515(13):2024.
Salgado I , Carmen Martnez M , Oliveira HC , Frungillo L. Nitric oxide signaling and homeostasis in plants: A focus on nitrate reductase and S-nitrosoglutathione reductase in stress-related responses. Rev. Bras. Bot. 2013;36(2):8998.
Savvides A , Ali S , Tester M , Fotopoulos V. Chemical priming of plants against multiple abiotic stresses: Mission possible? Trends Plant Sci. 2016;21(4):329340.
337 Sehrawat A , Abat JK , Deswal R. RuBisCO depletion improved proteome coverage of cold responsive S-nitrosylated targets in Brassica juncea. Front. Plant Sci. 2013;4:114.
Sehrawat A , Deswal R. S-nitrosylation analysis in Brassica juncea apoplast highlights the importance of nitric oxide in cold-stress signaling. J. Proteome Res. 2014;13(5):25992619.
Sengupta R , Holmgren A. The role of thioredoxin in the regulation of cellular processes by S-nitrosylation. Biochim. Biophys. Acta 2012;1820(6):689700.
Serrato AJ , Prez-Ruiz JM , Spnola MC , Cejudo F.J. A novel NADPH thioredoxin reductase, localised in the chloroplast, which deficiency causes hypersensitivity to abiotic stress in Arabidopsis thaliana. J. Biol. Chem. 2004;279(42):4382143827.
Sharma S , Sehrawat A , Deswal R. Asada-Halliwell pathway maintains redox status in Dioscorea alata tuber which helps in germination. Plant Sci. 2016;250:2029.
Sthr C , Strube F , Marx G , Ullrich WR , Rockel P. A plasma membrane-bound enzyme of tobacco roots catalyses the formation of nitric oxide from nitrite. Planta 2001;212(5):835841.
Stoimenova M , Igamberdiev AU , Gupta KJ , Hill R.D. Nitrite-driven anaerobic ATP synthesis in barley and rice root mitochondria. Planta 2007;226(2):465474.
Tanou G , Filippou P , Belghazi M , Job D , Diamantidis G , Fotopoulos V , et al. Oxidative and nitrosative-based signaling and associated post-translational modifications orchestrate the acclimation of citrus plants to salinity stress. Plant J. 2012;72(4):585599.
Thalineau E , Truong H-N , Berger A , Fournier C , Boscari A , Wendehenne D , et al. Cross-regulation between N metabolism and nitric oxide (NO) signaling during plant immunity. Front. Plant Sci. 2016;7:114.
Tielens AGM , Rotte C , Van Hellemond JJ , Martin W. Mitochondria as we dont know them. Trends Biochem. Sci. 2002;27(11):564572.
Tun NN , Santa-Catarina C , Begum T , Silveira V , Handro W , Segal Floh EI , et al. Polyamines induce rapid biosynthesis of nitric oxide (NO) in Arabidopsis thaliana seedlings. Plant Cell Physiol. 2006;47(3):346354.
Vetrovsky P , Stoclet JC , Entlicher G. Possible mechanism of nitric oxide production from N(G)-hydroxy-L-arginine or hydroxylamine by superoxide ion. Int. J. Biochem. Cell Biol. 1996;28(12):131113418.
Wang YQ , Feechan A , Yun BW , Shafiei R , Hofmann A , Taylor P , et al. S-nitrosylation of AtSABP3 antagonizes the expression of plant immunity. J. Biol. Chem. 2009;284(4):21312137.
Wilson ID , Neill SJ , Hancock J.T. Nitric oxide synthesis and signalling in plants. Plant Cell Environ. 2008;31(5):622631.
Yaacov YL , Wills RB , Ku V.V. Evidence for the function of the free radical gasnitric oxide (NO)as an endogenous maturation and senescence regulating factor in higher plants. Plant Phys. Biochem. 1998;36(11):825833.
Zaffagnini M , De Mia M , Morisse S , Di Giacinto N , Marchand CH , Maes A , et al. Protein S-nitrosylation in photosynthetic organisms: A comprehensive overview with future perspectives. Biochim. Biophys. Acta 2016;1864(8):952966.
Zhao M-G , Chen L , Zhang L-L , Zhang W-H. Nitric reductase-dependent nitric oxide production is involved in cold acclimation and freezing tolerance in Arabidopsis. Plant Physiol. 2009;151(2):755767.
Zhao R , Sheng J , Lv S , Zheng Y , Zhang J , Yu M , et al. Nitric oxide participates in the regulation of LeCBF1 gene expression and improves cold tolerance in harvested tomato fruit. Postharvest Biol. Technol. 2011;62(2):121126.
Ziogas V , Tanou G , Filippou P , Diamantidis G , Vasilakakis M , Fotopoulos V , et al. Nitrosative responses in citrus plants exposed to six abiotic stress conditions. Plant Physiol. Biochem. 2013;68:118126.

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Abbas S , Latif HH , Elsherbiny EA . Effect of 24-epibrassinolide on the physiological and genetic changes on two varieties of pepper under salt stress conditions. Pak. J. Bot. 2013;45:12731284.
Abbas W , Ashraf M , Akram N.A. Alleviation of salt induced adverse effects in eggplant (Solanum melongena) by glycinebetaine and sugarbeat extract. Sci. Hort. 2010;125:188195.
Ahmad P , Bhardwaj R , Tuteja N. , Prasad M.N.V. Plant signaling under abiotic stress environment. In: Environmental Adaptations and Stress Tolerance of Plants in the Era of Climate Change,. Ahmad P , Prasad M.N.V. (Eds.). New York: Springer, 2012; 297323.
Alam MM , Hayat S , Ali B , Ahmad A. Effect of 28 homo-brassinolide on nickel induced changes in Brassica juncea. Photosynthetica 2007;45:139142.
Ali B , Hassan SA , Hayat S , Hayat Q , Yadav S , Fariduddin Q , Ahmad A. Role for brassinosteroids in the amelioration of aluminium stress through antioxidant system in mung bean (Vigna radiata L. Wilczek). Environ. Exp. Bot. 2008a;62:153159.
Ali B , Hayat S , Ahmad A. 28homo-brassinolide ameliorates the saline stress in chickpea (Cicer arietinum). Environ. Exp. Bot. 2008b;59:217223.
352 Ali G , Hadi F , Ali Z , Tariq M , Khan M.A. Callus induction and in vitro complete plant regeneration of different cultivars of tobacco (Nicotiana tabacum L.) on media of different hormonal concentrations. Biotechnology 2007;4:561566.

Almeida JM , Fidalgo F , Confraria A , Santos A , Pires H , Santos I. Effect of hydrogen peroxide on catalase gene expression, isoform activities and levels in leaves of potato sprayed with homobrassinolide and ultrastructural changes in mesophyll cells. Funct. Plant Biol. 2005;32:707720.

Alyemeni MN , Hayat S , Wijaya L , Anaji A. Foliar application of 28-homobrassinolide mitigates salinity stress by increasing the efficiency of photosynthesis in Brassica juncea. Acta Bot. Brasilica 2013;27:502505.

Anuradha S , Rao S.S.R. Effect of 24-epibrassinolide on the growth and antioxidant enzym e activities in radish seedlings under lead toxicity. Indian J. Plant Physiol. 2007;12:396400.

Anuradha S , Rao S.S.R. The effect of brassinosteroids on radish (Raphanus sativus L.) seedlings growing under cadmium stress. Plant Soil Environ. 2003;53:465472.

Apel K , Hirt H. Reactive oxygen species: Metabolism, oxidative stress, and signal transduction. Annu. Rev. Plant Biol. 2004;55:373399.

Arafa AA , Khafagy MA , El-Banna M.F. The effect of glycinebetaine or ascorbic acid on grain germination and leaf structure of sorghum plants grown under salinity stress. Aust. J. Crop Sci. 2009;3:294304.

Arora A , Sairam RK , Srivastave G.C. Oxidative stress and antioxidative systems in plants. Curr. Sci. 2002;82:12271238.

Arora N , Bhardwaj R , Sharma P , Arora H.K. 28-homobrassinolide alleviates oxidative stress in salt treated maize (Zea mays L.) plants. Braz. J. Plant Physiol. 2008;20:153157.

Asada K , Takahashi M. Production and scavenging of active oxygen in photosynthesis. In: Photoinhibition: Topics in Photosynthesis. Kyle DJ, Osmond CB, Arnten C.J. (Eds.). Amsterdam: Elsevier, 1987; 9: 227287.

Ashraf M , Akram NA , Arteca RN , Fooled M.R. The Physiological biochemical and molecular roles of brassinosteroids and salicylic acid in plant processes and salt tolerance. Crit. Rev. Plant Sci. 2010;29:162190.

Athar HUR , Ashraf M. Modulation of growth, photosynthetic capacity and Ali Q, water relations in salt stressed wheat plants by exogenously applied 24-epibrassinolide. Plant Growth Regul. 2008;56:107116.

Baek KH , Skinner D.Z. Production of reactive oxygen species by freezing stress and the protective roles of antioxidant enzymes in plants. J. Agric. Chem. Environ. 2012;1:3440.

Bajguz A. Brassinosteroid enhanced the level of abscisic acid in Chlorella vulgaris subjected to short-term heat stress. J. Plant Physiol. 2009;166:882886.

Bajguz A , Hayat S. Effects of Brassinosteroids on the plant responses to environmental stresses. Plant Physiol. Biochem. 2008;8(47):18.

Belkhadir Y , Jaillais Y. The molecular circuitry of brassinosteroid signaling. New Phytol. 2015;206:522540.

Bethkey PC , Drew M.C. Stomatal and non-stomatal components to inhibition of photosynthesis in leaves of Capsicum annum during progressive exposure to NaCl. Plant Physiol. 1992;99(1):219226.

Bhardwaj R , Kaur S , Nagar PK , Arora H.K. Isolation and characterization of brassinosteroids from immature seeds of Camellia sinensis (O) Kuntze. Plant Grow Regul. 2007;53(1):15.

Borsani O , Valpuestan V , Botella M.A. Evidence for a role of salicylic acid in the oxidative damage generated by NaCl and osmotic stress in Arabidopsis seedlings. Plant Physiol. 2001;126:10241030.

Cabanero FJ , Martinez V , Carvajal M. Does calcium determine water uptake under saline conditions in pepper plants or is it water flux which determines calcium uptake. Plant Sci. 2004;166:443450.

Cao JJ , Chow J , Lee S , Li Y , Chen S , An Z. Characterization and source apportionment of atmospheric organic and elemental carbon during fall and winter of 2003 in Xian, China. Atmos. Chem. Phys. 2005;5:127137.

Cao L , Leers-Sucheta S , Azhar S. Aging alters the functional expression of enzymatic and non-enzymatic anti-oxidant defence systems in testicular rat Leydig cells. J. Steroid Biochem. Mol. Biol. 2004;88:6167.

Cardozo NP , Sentelhas P.C. Climatic effect on sugarcane ripening under the influence of cultivars and crop age. Sci. Agric. 2013;70(6):449456.

Cavusoglu K , Kabar K. Comparative effects on some plant growth regulator on the germination of barley and radish seeds under high tempera-ture stress. EurAsian J. BioSci. 2007;1:110.

Chaiwanon J , Wang Z.Y. Spatiotemporal brassinosteroid signaling and antagonism with auxin pattern stem cell dynamics in Arabidopsis roots. Curr. Biol. 2015;25:10311042.

Choe S. Brassinosteroid biosynthesis and metabolism. In: Plant Hormones: Biosynthesis, Signal Transduction, Action. Dordrecht: Kluwer Academic Publishers, 2007; 156178.

Choe S , Fujioka S , Noguchi T , Takatsuto S , Yoshida S , Feldmann K.A. Overexpression of DWARF4 in the brassinosteroid biosynthetic pathway results in increased vegetative growth and seed yield in Arabidopsis. Plant J. 2001;26:573582.

Chung Y , Choe S. The regulation of brassinosteroid biosynthesis in Arabidopsis. Crit. Rev. Plant Sci. 2013;32:396410.

Clouse S.D. Brassinosteroid signal transduction: From receptor kinase activation to transcriptional networks regulating plant development. Plant Cell 2011;23:12191230.

Clouse S.D. Molecular genetic analysis of brassinosteroid action. Physiol. Plant 1997;100:702709.

Clouse SD , Sasse J.M. Brassinosteroids: Essential regulators of plant growth and development. Annu. Rev. Plant Physiol. Mol. Biol. 1998;49:427451.

Cui JX , Zhou YH , Ding JG , Xia XJ , Shi K , Chen SC , Asami T , Chen Z , Yu J.Q. Role of nitric oxide in hydrogen peroxidedependent induction of abiotic stress tolerance by brassinosteroids in cucumber. Plant Cell Environ. 2011;34:347358.

Dhaubhadel S , Browning KS , Gallie DR , Krishna P. Brassinosteroid function to protect the translational machinery and heat shock protein synthesis following thermal stress. Plant J. 2002;29(6):681691.

Dhaubhadel S , Chaudhary S , Dobinson KF , Krishna P. Treatment with 24-epibrassinolide, a brassinosteroid, increases the basic thermotolerance of Brassica napus and tomato seedlings. Plant Mol. Biol. 1999;40:333342.

Ding HD , Zhu XH , Zhu ZW , Yang SJ , Zha DS , Wu X.X. Amelioration of salt induced oxidative stress in eggplant by application of 24-epibrassinolide. Biol. Plant. 2012;56:767770.

Ding J , Shi K , Zhou YH , Yu J.Q. Effects of root and foliar applications of 24-epibrassinolide on fusarium wilt and antioxidant metabolism in cucumber roots. Hort. Sci. 2009a;44(5):13401349.

353 Ding J , Shi K , Zhou YH , Yu J.Q. Microbial community responses associated with the development of Fusarium oxysporium sp. Cucumerinum after 24-epibrassinolide applications to shoots and roots in cucumber. Eur. J. Plant Pathol. 2009b;124:141150.

Divi UK , Krishna P. Brassinosteroid: A biotechnological target for enhancing crop yield and stress tolerance. New Biotech. 2009;26:131136.

Divi UK , Krishna P. Overexpression of the Brassinosteroid biosynthetic gene AtDWF4 in Arabidopsis seeds overcomes Abscisic acid-induced inhibition of germination and increases cold tolerance in transgenic seedling. J. Plant Growth Regul. 2010;29:385393.

Divi UK , Rahman T , Krishna P. Brassinosteroid-mediated stress tolerance in Arabidopsis shows interactions with abscisic acid, ethylene and salicylic acid pathways. BMC Plant Biol. 2010;10:151.

Divi UK , Rahman T , Krishna P. Gene expression and functional analyses in brassinosteroid-mediated stress tolerance. Plant Biotechnol. 2015;14:419432.

El-Khallal SM , Hathout TA , Ashour Aera , Kerrit Aaa . Brassinolide and salicylic acid induced antioxidant enzymes, hormonal balance and protein profile of maize plants grown under salt stress. Res. J. Agric. Biol. Sci. 2009;5:391402.

El-Mashad AA , Mohamed H.I. Brassinolide aaleviates salt stress and increase antioxidant activity of cowpea plants (Vigna sinensis). Protoplasma 2012;249:625635.

Fariduddin Q , Khanam S , Hasan SA , Ali B , Hayat SA , Ahmad A. Effect of 28- homobrassinolide on the drought stress-induced changes in photosynthesis and antioxidant system of Brassica juncea L. Acta Physiol. Plant 2009;31:889897.

Fariduddin Q , Mir BA , Yusuf M , Ahmad A. Comparative roles of brassinosteroids and polyamines in salt stress tolerance. Acta Physiol. Plant 2013;35:20372053.

Fariduddin Q , Yusuf M , Begum M , Ahmad A. 28- homobrassinolide protect photosynthetic machinery in Indian mustard high temperature stress. J. Stress Physiol. Biochem. 2014;10:181194.

Fariduddin Q , Yusuf M , Chalkoo S , Hayat S , Ahmad A. 28- homobrassinolide improves growth and photosynthesis in Cucumis sativus L. through an enchanced antioxidant system in the presence of chilling stress. Photosynthetica 2011;49:5564.

Farrell TC , Fox KM , Williams RL , Fukai S. Genotypic variation for cold tolerance during reproductive development in rice: Screening with cold air and cold water. Field Crops Res. 2006;98:178194.

Finkelstein RR , Gampala SSL , Rock C.D. Abscisic acid signaling in seeds and seedlings. Plant Cell 2002;14:S15S45.

Fujioka S , Noguchi T , Yokota T , Takatsuto S , Yoshida S. Brassinosteroids in Arabidopsis thaliana. Phytochemistry 1998;48:595599.

Fujioka S , Yokota T. Biosynthesis and metabolism of brassinosteroids. Annu. Rev. Plant Biol. 2003;54:137164.

Goda H , Shimada Y , Asami T , Fujioka S , Yoshida S. Microarray analysis of brassinosteroid regulated genes in Arabidopsis. Plant Physiol 2002;130:13191334.

Greenway H , Gibbs J. Mechanisms of anoxia tolerance in plants. II. Energy requirements for maintenance and energy distribution to essential processes. Funct. Plant Biol. 2003;30:9991036.

Grove MD , Spencer GF , Rohwedder WK , Mandava N , Worley JF , Jdw, Steffens GL, Flippen-Anderson JL, Carter Cook J. Brassinolide, a plant growth-promoting steroid isolated from Brassica napus pollen. Nature 1979;281:216217.

Guo H , Li L , Aluru M , Aluru S , Yin Y. Mechanisms and networks for brassinosteroid regulated gene expression. Curr. Opin. Plant Biol. 2013;16:545553.

Halliwell B , Gutteridge J.M.C. Free radicals in biology and medicine. Oxford University Press, Oxford 1999;125.

Hao JJ , Yin YH , Fei S.Z. Brassinosteroid signaling network: Implications on yield and stress tolerance. Plant Cell Rep. 2013;32:10171030.

Hare PD , Cress WA , Staden J. The involvement of cytokinins in plant responses to environmental stress. Plant Growth Regul. 1998;23:79103.

Hasanuzzaman M , Nahar K , Fujita M. Extreme temperatures, oxidative stress and antioxidant defense in plants. Abiotic StressPlant Responses and Applications in Agriculture 2013;10:169205.

Hasanuzzaman M , Nahar K , Fujita M. Regulatory role of polyamines in growth, development and abiotic stress tolerance in plants. In: Plant Adaptation to Environmental Change: Significance of Amino Acids and Their Derivatives. Anjum NA, Gill SS, Gill R. (Eds.). Boston: CABI, 2014; 157 157.

Hategan L , Godza B , Szekeres M. Regulation of brassinosteroid metabolism. In: Brassinosteroids: A Class of Plant Hormone. Hayat S, Ahmed A. (Eds.) New York: Springer, 2011; 5781.

Haubrick LL , Assmann S.M. Brassinosteroids and plant function: some clues, more puzzles. Plant Cell Environ. 2006;29:446457.

Hayat S , Ali B , Hassan SA , Ahmad A. Effects of 28- homobrassinolide on salinity-induced changes in Brassica juncea. Turk. J. Biol. 2007;31:141146.

Hayat S , Hasan SA , Hayat Q , Ahmad A. Brassinosteroids protect Lycopersicon esculentum from cadmium toxicity applied as shotgun approach. Protoplasma 2010a;239:314.

Hayat S , Hasan SA , Yusuf M , Hayat Q , Ahmad A. Effect of 28-homobrassinolide on photosynthesis, fluorescence and antioxidant system in the presence or absence of salinity and temperature in Vigna radiate. Environ. Exp. Bot. 2010b;69:105112.

Hojin R , Yong G.C. Plant hormones in salt stress tolerance. J. Plant Biol. 2015;58:147155.

Hoque MA , Banu MNA , Okuma E. Exogenous proline and glycinebetaine increase NaCl-induced ascorbate-glutathione cycle enzyme activities, and proline improves salt tolerance more than glycinebetaine in tobacco Bright Yellow-2 suspension-cultured cells. J. Plant Physiol. 200b;164:14571468.

Hoque MA , Okuma E , Banu MNA , Nakamura Y , Shimoishi Y , Murata Y. Exogenous proline mitigates the Detrimental effects of salt stress more than exogenous betaine by increasing antioxidant enzyme activities. J. Plant Physiol. 2007a;164:553561.

Hu H , You J , Fang Y , Zhu X , Qi Z , Xiong L. Characterization of transcription factor gene SNAC2 conferring cold and salt tolerance in rice. Plant Mol. Biol. 2008;67:169181.

Hu Y , Yu D. BRASSINOSTEROID INSENSITIVE2 interacts with ABSCISIC ACID INSENSITIVE5 to mediate the antagonism of brassinosteroids to abscisic acid during seed germination in Arabidopsis. Plant Cell 2014;26:43944408.

Huang B , Chu CH , Chen SL , Juan HF , Chen YM . A proteomics study of the mung bean epicotyl regulated by brassinosteroids under conditions of chilling stress. Cell Mol Biol Lett. 2006;11(2):264278.

354 Ikekawa N , Zhao Y.J. Application of 24-epibrassinolide in agriculture. In: Cutler HG, Yokota T, Adam G, eds. Brassinosteroids. Chemistry, bioactivity, and applications. ACS Symposium Series, 474. Washington: American Chemical Society 1991;474:280291.

Jan N , Hussain MU , Andrabi K.I. Cold resistance in plants: A mystery unresolved. Electron. J. Biotechnol. 2009;15:12.

Janeczko A , Gullner G , Skoczowski A , Dubert F , Barna B. Effects of brassinosteroid infiltration prior to cold treatment on ion leakage and pigment contents in rape leaves. Biol. Plant. 2007;51:355358.

Janeczko A , Oklestkova J , Pociecha E , Koscielniak J , Mirek M. Physiological effects and transport of 24-epibrassinolide in heat-stressed barley. Acta Physiol. Plant 2011;233:12491259.

Je BI , Piao HL , Park SJ , Park SH , Kim CM , Xuan Y.H. RAV-Like1 maintains brassinosteroid homeostasis via the coordinated activation of BRI1 and biosynthetic genes in rice. Plant Cell 2010;22(6):17771791.

Jiang Y , Huang B. Drought and heat stress injury to two cool season turfgrasses in relation to antioxidant metabolism and lipid peroxidation. Crop Sci. 2001;41:436442.

Jiang YP , Huang LF , Cheng F , Zhou YH , Xia XJ , Mao WH , Shi K , Yu J.Q. Brassinosteroids accelerate recovery of photosynthetic apparatus from cold stress by balancing the electron partitioning, carboxylation and redox homeostasis in cucumber. Physiol. Plant. 2013;148:133145.

Kagale S , Divi UK , Krochko JE , Keller WA , Krishna P. Brassinosteroids confers tolerance in Arabidopsis thaliana and Brassica napus to a range of abiotic stresses. Planta 2007;225(2):353364.

Kaur H , Sirhindi G , Bhardwaj R. Influence of 28-homobrassinolide on photochemical efficiency in Brassica juncea under dual stress of extreme temperatures and salt. Canadian Journal of Pure and Applied Sciences 2017;11:42054213.

Kaur H , Sirhindi G , Bhardwaj R. Aiternation of antioxidant machinery by 28-homobrassinolide in Brassica juncea L. under salt stress. Adv. Appl. Sci. Res. 2015;6:166172.

Kaur H , Sirhindi G , Bhardwaj R , Sharma P , Mudasir M. 28-homobrassinolide modulate antenna complexes and carbon skeleton of Brassica juncea L. under temperature stress. J. Stress Physiol. Biochem. 2014;10:186196.
Kaur N , Patti P.K. Integrating classical with emerging concepts for better understanding of salinity stress tolerance mechanisms in rice. Environ. Sci. 2017;5:42.
Khafagy MA , Arafa AA , El-Banna M.F. Glycinebetaine and ascorbic acid can alleviate the harmful effects of NaCl salinity in sweet pepper. Aust. J. Crop Sci. 2009;3:257267.
Khan NA , Singh S. Abiotic Stress and Responses. New Delhi: IK International Publishing House Private. Limited, 2008.
Kim BK , Fujioka S , Takatsuto S , Tsujimoto M , Choe S. Castasterone is a likely end product of brassinosteroid biosynthetic pathway in rice. Biochem. Biophys. Res. Commun. 2008;374:614619.
Kim TW , Michniewicz M , Bergmann DC , Wang Z.Y. Brassinosteroid regulates stomatal development by GSK3-mediated inhibition of a MAPK pathway. Nature 2012;482:419 419.
Kitanaga Y , Jian C , Hasegawa M , Yazaki J , Kishimoto N , Kikuchi S. Sequential regulation of gibberellin, brassinosteroid, and jasmonic acid biosynthesis occurs in rice coleoptiles to control the transcript levels of anti-microbial thionin genes. Biosci. Biotechnol. Biochem. 2006;70:24102419.
Koh S , Lee SC , Kim MK , Koh JH , Lee S G, Choe S, Kim SR. T-DNA tagged knockout mutation of rice OsGSK1, an orthologue of Arabidopsis BIN2, with enhanced tolerance to various abiotic stresses. Plant Mol. Biol. 2007;65:453466.
Kolupaev Y , Akinina G , Mokrousov A. Induction of heat tolerance in wheat coleoptiles by calcium ions and its relation to oxidative stress. Russian J. Plant Physiol. 2005;52:199204.
Kovtun Y , Chiu WL , Tena S.J. Fuctional analysis of oxidative stress-activated mitogen-activated protein kinase cascade in plants. Proc. Natl. Acad. Sci. USA 2000;97:29402945.
Krishna P. Brassinosteroid-mediated stress responses. J. Plant Growth Regul. 2003;22:289 289.
Kumar A , DSouza SS , Tickoo S , Salimath BP , Singh H.B. Antiangiogenic and proapoptotic activities of allyl isothiocyanate inhibit ascites tumor growth in vivo. Integr. Cancer Ther. 2009;8:7587.
Kumar M , Sirhindi G , Bhrdwaj R , Kumar S , Jain G. Effect of exogenous H2O2 on antioixidant enzymes of Brassica juncea L. seedling in relation to 24-epibrassinolide under chilling stress. Ind. J. Biochem. Biophys. 2010;47(6):378 378.
Kumar S , Dubey RS , Tripathi RD , Chakrabarty D , Trivedi P.K. Omics and biotechnology of arsenic stress and detoxification in plants: Current updates and prospective. Environ. Int. 2015;74:221230.
Kumar S , Singh D , Dutta M. Quality characteristics in rapeseed-mustard and role of some antinutritional factors in plant defense: Future strategies. J. Oilseed Brassica 2014;5:8795.
Kumar S , Sirhindi G , Bhardwaj R. 28- homobrassinolide induced exaggerated growth, biochemical molecular aspects of Brassica juncea L. RLM-619 seedling under high temperature stress. Plant Biochem. Physiol. 2014;2:127.
Kumar S , Sirhindi G , Bhardwaj R , Kimar M , Arora P. Role of 24-epibrassinolide in amelioration of high temperature stress through antioxidant defence system in Brassica juncea L. Plant Stress 2012;5558.
Levitt J. Responses of plant to environmental stress Volume 1:Chilling, Freezing, and High Temperature Stress., London:Academic Press. 1980.
Li JM , Chory J. Brassinosteroid actions in plants. J. Exp. Bot. 1999;50:275282.
Li KR , Wang HH , Han G , Wang QJ , Fan J. Effect of brassinolide on the survival, growth and drought resistance of Robinia pseudoacacia seedling under water stress. New Forests 2008;35:255266.
Li QF , Wang C , Jiang L , Li S , Sun SS , He J.X. An interaction between BZR1 and DELLAs mediates direct signaling crosstalk between brassinosteroids and gibberellins in Arabidopsis. Sci. Signal. 2012;5:ra72.
Liqiong X , Yang C , Wang X. Brassinosteroids can regulate cellulose biosynthesis by controlling the expression of CESA genes in Arabidopsis. J. Exp. Bot. 2011;62(13):44954506.
Liu ZJ , Zhang XL , Bai JG , Suo BX , Xu PL , Wang L. Exogenous paraquat changes antioxidant enzymes activities and lipid peroxidation in drought stressed cucumber leaves. Sci. Hort. 2009;121:138143.
Lopez-Molina L , Mongrand B , McLachlin DT , Chait BT , Chua N.H. ABI5 acts downstream of ABI3 to execute an ABA dependent growth arrest during germination. Plant J. 2002;32:317328.
Lu XM , Yang W. Alleviation effects of brassinolide on cucumber seedlings under NaCl stress. Ying Yong Sheng Tai Xue Bao 2013;24:14091414.
355 Lu Y , Zhao L , Wang B. From virtual community members to c2c e-commerce buyers: trust in virtual communities and its effect on consumers purchase intention. Electronic Commerce Research & Applications 2010;94:346360.
Maestri E , Klueva N , Perrotta C , Gulli M , Nguyen HT , Marmiroli N. Molecular genetics of heat tolerance and heat shock proteins in cereals. Plant Mol. Biol. 2002;48:667681.
Mahajan S , Tuteja N. Cold, salinity and drought stresses: An overview. Arch. Biochem. Biophys. 2005;444:139158.
Maharjan PM , Choe S. High temperature stimulates DWARF4 (DWF4) expression to increase hypocotyle elongation in Arabidopsis. J. Plant Biol. 2011;54:425429.
Manavalan LP , Chen X , Clarke J , Salmeron J , Nguyen H.T. RNAi-mediated disruption of squalene synthase improves drought tolerance and yield in rice. J. Exp. Bot. 2012;63:163175.
Mandava NB , Mitchell J.W. Structural elucidation of brassins. Chem. Ind. 1972;930932.
Mandava NB , Sidwell BA , Mitchell JW , Worley J.F. Production of brassins from rape pollen: A convenient preparative method. Ind. Eng. Chem. Prod. Res. Dev. 1973;12:138139.
Marakali S , Temel A , Nermin G. Salt stress and homobrassinosteroid interactions during germination in barley roots. Not. Bot. Horti Agrobot. Cluj-Napoca 2014;42(2):446452.
Marco A , Zullo T , Adam G. Brassinosteroid phytohormones - structure, bioactivity and applications. Brazilian Journal of Plant Physiology 2002;14:143181.
Marsolais F , Boyd J , Paredes Y , Schinas AM , Garcia M , Elzein S. Molecular and biochemical characterization of two brassinosteroid sulfotransferases from Arabidopsis, AtST4a (At2g14920) and AtST1 (At2g03760). Planta 2007;225:12331244.
Mazorra LM , Nunez M , Hechavarria M , Coll F , Sanchez-Blanco M.J. Influence of brassinosteroids on antioxidant enzymes activity in tomato under different temperatures. Biol. Plant. 2002;45:593596.
McCord J.M. The evolution of free redicals and oxidative stress. Am. J. Med. 2000;108:652659.
McCue AM , Hanson A. Drought and salt tolerance: toward understanding and application. Trends Biotechnol. 1990;8:358362.
Metwally A , Finkermeier I , Georgi M , Dietz K.J. Salicylic acid alleviates the cadmium toxicity in barley seedlings. Plant Physiol. 2003;132:272281.
Mitchell JW , Mandava NB , Worley JF , Plimmer JR , Smith M.V. Brassins a new family of plant hormones from rape pollen. Nature 1970;225:10651066.
Mitchell R , Stocklin W , Stefanovi M , Geissman T. Chap-arrolide and castelanolide, New bitter principles from castela nicholsoni. Phytochemistry 1971;10:411417.

Mittler R. Oxidative stress, antioxidants and stress tolerance. Trends Plant Sci. 2002;7:405410.
Morales D , Rodrigues P , Dell Amico J , Nicolas E , Torrecillas A , Sanchez-Blanco M.J. High temperature preconditioning and thermal shock imposition affects water relations, gas exchange and root hydraulic conductivity in tomato. Biol. Plant. 2003;47:203208.
Munns R , Tester M. Mechanisms of salinity tolerance. Annu. Rev. Plant Biol. 2008;59:651681.
Mssig C , Fischer S , Altman T. Brassinosteroid regulated gene exression. Plant Physiol. 2002;129:12411251.
Nakano Y , Higuchi Y , Sumitomo K , Hisamatsu T. Flowering retardation by high temperature in chrysanthemums: Involvement of FLOWERING LOCUS T- like 3 gene repression. J. Exp. Bot. 2013;64:909920.
Nassar A.H. Effect of homobrassinolide on in vitro growth of apical meristems and heat tolerance of banana shoots. Int. J. Agric. Boil. 2004;771775.
Nasser AM , Mohammed A.S. Effect of 28- homobrassinolide on the drought induced changes in the seeds of Vigna radiate. Legume Res. 2014;37:515519.
Noctor G , Foyer C. Ascorbate and glutathione: Keeping active oxygen under control. Annu. Rev. Plant Physiol. Plant Mol. Biol. 1998;49:249279.
Nogues S. Brassinosteroids alleviate heat induced inhibition of photosynthesis by increasing carboxylation efficiency and enhancing antioxidant systems in Lycopersicon esculentum. J. Plant Growth Regul. 2008;27:4957.
Noreen Z , Ashraf M. Assessment of variation in antioxidative defense system in salt- treated pea (Pisum sativum) cultivars and its putative use as salinity tolerance markers. J. Plant Physiol. 2009;166:17641774.
Nunez M , Mazzafera P , Mazorra LM , Siqueira WJ , Zullo M.A.T. Influence of brassinosteroid analogue on antioxidant enzymes in rice grown in culture medium with NaCl. Biol Plant. 2003;47:6770.
Ogweno JO , Song XS , Shi K , Hu WH , Mao WH , Zhou YH , Yu JQ , Nogues S. Brassinosteroids Allivate Heat-induced inhibition of photosynthesis by increasing carboxylation efficiency and enhancing antioxidant system in Lycopersicon esculentum. J. Plant G rowth Regul. 2008;27:49 49.
Ohnishi ST , Godza B , Watanabe B , Fujioka S , Hategan L , Ide K , Shibata K, Yokota T, Szkeres M, Mizutani M. CYP90A1/CPD, a brassinosteroid biosynthetic cytochrome P450 of Arabidopsis, catalyzes C-3 oxidation. J. Biol. Chem. 2012;287:3155131560.
zdemir F , Bor M , Demiral T , Turkan I. Effect of 24-epibrassinolide on seed germination, seedling growth, lipid peroxidation, proline content and antioxidant system of rice (Oryza sativa L.) under salinity stress. Plant Growth Regul. 2004;41:19.
Patel D , Franklin K.A. Temperature regulation of plant architecture. Plant Signal. Behav. 2009;4:577579.
Piol R , Simn E. Effect of 24-epibrassinolide on chlorophyll fluorescence and photosynthetic CO2 assimilation in Vicia faba plants treated with the photosynthesis-inhibiting herbicide terbutryn. J. Plant Growth Regul. 2009;28:97105.
Poppenberger B , Fujioka S , Soeno K , George GL , Vaistij FE , Hiranuma S. The UGT73C5 of Arabidopsis thaliana glucosylates brassinosteroids. Proc. Natl. Acad. Sci. USA 2005;102:1525315258.
Poppenberger B , Rozhon W , Khan M , Husar S , Adam G , Luschnig C. CESTA, a positive regulator of brassinosteroid biosynthesis. EMBO J. 2011;30:11491161.
Prasad PVV , Boote LH , Allen JR , Sheehy JE , Thomas J.M.G. Species, ecotype and cultivar differences in spikelet fertility and harvest index of rice in response to high temperature stress. Field Crops Res. 2006;95:398411.
Rady M.M. Effect of 24-epibrassinolide on growth, yield, antioxidant system and cadmium content of bean (Phaseolus vulgaris L.) plants under salinity and cadmium stress. Sci. Hort. 2011;129(2):232 232.
356 Ramakrishna A , Ravishankar G.A. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal. Behav. 2011;6:17201731.
Ramakrishna B , Rao S.S.R. 24-epibrassinolide alleviated zinc-induced oxidative stress in radish (Raphanus sativus L.) seedlings by enhancing antioxidative system. Plant Growth Regul. 2012;68:249259.
Rao AAR , Vardhini BV , Sujatha E , Anuradha S. Brassinosteroids a new class of phytohormones. Curr. Sci. 2002;82:12391245.
Rattan A , Kapoor N , Bhardwaj R. Role of brassinosteroids in osmolytes accumulation under salinity stress in Zea mays plants. Int. J. Sci. Res. 2012;3:18221827.
Roh H , Jeong CW , Fujioka S , Kim YK , Lee S , Ahn J.H. Genetic evidence for the reduction of brassinosteroid levels by a BAHD acyltransferase-like protein in Arabidopsis. Plant Physiol. 2012;159:696709.
Ryu H , Hwang I. Brassinosteroids in plant developmental signaling networks. J. Plant Biol. 2013;56:267273.
Saini S , Sharma I , Pati PK . Versatile roles of brassinosteroid in plants in the context of its homoeostasis, signaling and crosstalks. Front. Plant Sci. 2015;6:950.
Sakamoto A , Murata N. The role of glycine betaine in the protection of plants from stress: Clues from transgenic plants. Plant Cell Environ. 2002;25:163171.
Sanghera GS , Wani SH , Hussain W , Singh N.B. Engineering cold stress tolerance in crop plants. Curr. Genom. 2011;12(1):3043.
Satake T , Yoshida S. High temperature induced sterility in Indica rice at flowering. Jpn. J. Crop Sci. 1978;47:617.
Schneider K , Breuer C , Kawamura A , Jikumaru Y , Hanada A , Fujioka S , Ichikawa T , Kondou Y , Matsui M , Kamiya Y , Yamaguchi S , Sugimoto K . Arabidopsis pizza has capacity to acylate brassinosteroids. PLoS One 2012;7:46805.
Sehrawat N , Bhat KV , Sairam RK , Jaiwal P.K. Screening of mungbean (Vigna radiata L. Wilczek) genotypes for salt tolerance. Int. J. Plant Anim. Environ. Sci. 2013a;4:3643.
Sehrawat N , Bhat KV , Sairam RK , Tomooka N , Kaga A , Shu Y , Jaiwal P.K. Diversity analysis and confirmation of intra-specific hybrids for salt tolerance in mungbean (Vigna radiata L. Wilczek). Int. J. Integr. Biol. 2013b;14:6573.
Sehrawat N , Jaiwal PK , Yadav M , Bhat KV , Sairam R.K. Salinity stress restraining mungbean (Vigna radiata L. Wilczek) production: Gateway for genetic improvement. Int. J. Agric. Crop Sci. 2013c;6:505509.
Serna M , Yamilet CB , Pedro J , Zapataa AB , Maria TPA , Asunction A.A. Brassinosteroid analogue prevented the effect of salt stress on ethylene synthesis and polyamines in lettuce plants. Sci. Hort. 2015;185:105112.
Shahbaz M , Ashraf M. Influence of Exogenous application of Brassinosteroids on growth and mineral nutrients of wheat (Triticum aestivum L.) under saline conditions. Pak. J. Bot. 2007;39(2):513522.
Shahbaz M , Nasreen S , Afza T. Environmental consequences of economic growth and foreign direct investment: evidence from panel data analysis. Bull. Energy Econ. 2014;2:1427.
Shahid MA , Pervez MA , Balal RM , Mattson, Rashid A , Ahmad R , Ayyub CM , Abbas T. Brassinosteroid (24-epibrassinolide) enhances growth and alleviates the deleterious effects induced by salt stress in pea (Pisum sativum L.). Austral. J. Crop Sci. 2011;5(5):500510.
Shang Q , Song S , Zhang Z , Guo S. Exogenous brassinosteroid induced salt resistance of cucumber (Cucumis sativus L.) seedlings. Sci. Agric. Sin. 2006;39:18721877.
Sharkova V.E. The effect of heat shock on the capacity of wheat plants to restore their photosynthesis electron transport after photoinhibition or repeated heating. Russian J. Plant Physiol. 2001;48:793797.
Sharma RK , Agrawal M , Marshall F.M. Heavy metals contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotox. Environ. Saf. 2007;66:258266.

Sharma I , Bhardwaj R , Pati P.K. Exogenous application of 28-Homobrassinolide modulates the dynamics of salt and pesticides induced stress responses in an elite rice variety Pusa Basmati-1. J. Plant Growth Regul. 2015;34:509518.
Sharma I , Ching E , Saini S , Bhardwaj R , Pati P.K. Exogenous application of brassinosteroid offers tolerance to salinity by altering stress responses in rice variety Pusa Basmati-1. Plant Physiol. Biochem. 2013;69:1726.
Simoes-Araujo JL , Rumjanek NG , Margis-Pinheiro M. Small heat shock proteins genes are differentially expressed in distinct varieties of common bean. Brazilian J. Plant Physiol. 2003;15:1133.
Singh I , Shono M. Physiological and molecular effects of 24-epibrassinolide, a brassinosteroid on thermotolerance of tomato. Plant Growth Regul. 2005;47:111119.
Sirhindi G , Kaur H , Bhardwaj R , Kaur NP , Sharma P. Thermo protective role of 28- homobrassinolide in Brassica juncea plants. Am. J. Plant Sci. 2014;5:4807448079.
Sirhindi G , Kumar S , Bhardwaj R , Kumar M. Effect of 24-epibrassinolide and 28-homobrassinolide on the growth and antioxidant enzymes activities in the seedling of Brassica juncea L. Physiol. Mol. Biol. Plants 2009;15:335341.
Sirhindi G , Mir MA , Abd-Allah EF , Ahmad P , Gucel S. Jasmonic acid modulates the physio-biochemical attributes,antioxidant enzyme activity, and gene expression in glycine max under nickel toxicity. Front. Plant Sci. 2016;7:591.
Sirhindi G , Mir MA , Sharma P , Gill SS , Kaur H , Mushtaq R. Modulatory role of jasmonic acid on photosynthetic pigments, antioxidants and stress markers of Glycine max L. under nickel stress. Physiol. Mol. Biol. Plants. 2015;4:559565.
Song WJ , Zhou WJ , Jin ZL , Zhang D , Takeyuchi Y , Joel D.M. Growth regulators restore germination of Orobanche seeds that are conditioned under water stress and suboptimal temperature. Aust. J. Agric. Res. 2006;57:11951201.
Soussi M , Dcana A , Lluch C. Effect of salt stress on growth, photosynthesis and nitrogen fixation in chickpea (Cicer arietinum L.). J. Exp. Bot. 1998;49:13271329.
Sreeramulu S , Mostizky Y , Sunitha S , Shani E , Nahum H , Salomon D. BSKs are partially redundant positive regulators of brassinosteroid signaling in Arabidopsis. Plant J. 2013;74:905919.
Steber CM , McCourt P. A role for brassinosteroids in germination in Arabidopsis. Plant Physiol. 2001;125:763769.
Steponkus PL , Uemura M , Webb M.S. A contrast of the cryostability of the plasma membrane of winter rye and spring oat-two species that widely differ in their freezing tolerance and plasma membrane lipid composition. In: Advances in Low Temperature Biology. Steponkus PL (Ed.). London: JAI Press, 1993; 2: 211312.
357 Sudhir P, Murthy SDS. Effects of salt stress on basic processes of photosynthesis. Photosynthetica 2004;42:481486.
Sun Y , Fan XY , Cao DM , Tang W , He K , Zhu J.Y. Integration of brassinosteroid signal transduction with the transcription network for plant growth regulation in Arabidopsis. Dev. Cell 2010;19:765777.
Symons GM , Ross JJ , Jager CE , Reid J.B. Brassinosteroid transport. J. Exp. Bot. 2008;59:1724.
Tanaka K , Asami T , Yoshida S , Nakamura Y , Matsuo T , Okamoto S. Brassinosteroid homeostasis in Arabidopsis is ensured by feedback expressions of multiple genes involved in its metabolism. Plant Physiol. 2005;138:11171125.
Tikhomirov AA , Zolotukhin IG , Lisovskii GM , Sidko F.Y. Specificity of responses to the spectral composition of the PAR in plants of different species under artificial illumination. Soviet Plant Physiol. 1987;34:624633.
Tong H , Xiao Y , Liu D , Gao S , Liu L , Yin Y. Brassinosteroid reg ulates cell elongation by modulating gibberellin metabolism in rice. Plant Cell 2014;26:43764393.
Tuteja N. Mechanism of high salinity tolerance in plants. Methods Enzymol. 2007; 428: 218419.
Tuteja N. Cold, salt and drought stress. In: Plant Stress Biology: From Genomics Towards System Biology. Heribert, H. (Ed.). Weinheim, Germany: WileyBlackwell, 2010; 137159.
Vahala J , Keinanen M , Schutzendubel A , Polle A , Kangasjarvi J. Differential effects of elevated ozone on two hybrid aspen genotypes predisposed to chronic ozone fumigation role of ethylene and salicylic acid. Plant Physiol. 2003;132:196205.
Vardhini B.V. Comparative study of Sorghum vulgare Pers. Grown in two experimental sites by brassinolide application at vegetative, flowering and grain filling stage. Proc. Andhra Pradesh Akad. Sci. 2013;15:7579.
Vardhini B.V. Studies on the effect of brassinolide on the antioxidative system of two varieties of sorghum grown in saline soils of Karaikal. Asian Aust. J. Plant Sci. Biotechnol. 2011;5:3134.
Vardhini BV , Anjum N.A. Brassinosteroids make plant life easier under abiotic stresses mainly by modulating major components of antioxidant defense system. Front. Environ. Sci. 2015;21:7075.
Vardhini BV , Anjum NA , Gill SS , Gill R. Brassinosteroids role for amino acids, peptides and amines modulation in stressed plants are view. In: Plant Adaptation to Environmental Change: Significance of Amino Acids and their Derivatives. Wallingford, CT: CAB International, 2013; 300316.
Vardhini BV , Anuradha S , Rao S.S.R. Brassinosteroids a great potential to improve crop productivity. Indian J. Plant Physiol. 2006;11:112.
Vollenweider P , Gunthardt-Goerg M.S. Diagnosis of abiotic and biotic stress factors using the visible symptoms in foliage. Environ. Pollut. 2005;137:455465.
Vriet C , Russinova E , Reuzeau C. From squalene to brassinolide: The steroid metabolic and signaling pathways across the plant kingdom. Mol. Plant 2013;6:17381757.
Wachsman MB , Ramirez JA , Talarico LB , Galagovsky LR , Coto C.E. Anti viral activity of natural and synthetic brassinosteroids. Curr. Med. Chem. Anti Infective Agents 2004;3:163179.
Wahid A , Gelani S , Ashraf M , Foolad M.R. Heat tolerance in plant: An overview. Environ. Exp. Bot. 2007;61:199223.
Wahid A , Shabbir A. Induction of heat stress tolerance in Barley seedlings by pre sowing seed treatment with glycinebetaine. Plant Growth Regul. 2005;46:133141.
Wang B , Zeng G. Effect of 24-epibrassinolide on the resistance of rice seedlings to chilling injury. Zhiwa Shengi Xuebao 1993;19:5360.
Wang H , Nagegowda DA , Rawat R , Bouvier-Nave P , Guo D , Bach T.J. Overexpression of Brassica juncea wild-type and mutant HMG-CoA synthase 1 in Arabidopsis upregulates genes in sterol biosynthesis and enhances sterol production and stress tolerance. Plant Biotechnol. J. 2012;10:3142.
Wilen RW , Sacco M , Gusta LV , Krishna P. Effects of 24-epibrassinolide on freezing and thermo tolerance of brome grass (Bromusinermis) cell cultures. Physiol. Plant. 1995;95:195202.
Wise R , Olson A , Schrader S , Sharkey T. Electron transport is the functional limitation of photosynthesis in field-grown pima cotton plants at high temperature. Plant Cell Environ. 2004;27:717724.
Wu L , Zhang Z , Zhang H , Wang XC , Huang R. Transcriptional modulation of ethylene response factor protein JERF3 in the oxidative stress response enhances tolerance of tobacco seedlings to salt, drought, and freezing. Plant Physiol. 2008;148:19531963.
Wu X , Oh MH , Kim HS , Schwartz D , Imai BS , Yau P.M. Transphosphorylation of E. coli proteins during production of recombinant protein kinases provides a robust system to characterize kinase specificity. Front. Plant Sci. 2012;3:262.
Xia XJ , Huang YY , Wang L , Huang LF , Yu YL , Zhou YH , Yu J.Q. Pesticides induced depression of photosynthesis was alleviated by 24- epibrassinolide pretreatment in Cucumis sativus L. Pestic. Biochem. Physiol. 2006;86:4248.

Xia XJ , Wang YJ , Zhou YH , Tao Y , Mao WH , Shi K , Asami T , Chen Z , Yu J.Q. Reactive oxygen species are involve in brassinosteroid- induced stress tolerance in cucumber. Plant Physiol. 2009;150:801814.
Xia XJ , Zhou YH , Ding J , Shi K , Asami T , Chen Z. Induction of systemic stress tolerance by brassinosteroid in Cucumis sativus. New Phytol. 2011;191:706720.
Xiao-Jian X , Yan J, Yan-Hong Z , Yuan T , Wei-Hua M , Kai S , Tadao A , Zhixiang C , Jing Q. Reactive oxygen species are involved in brassinosteroid-induced stress tolerance in cucumber. Plant Physiol. 2009;150(2):801804.
Xu S , Li J , Zhang X , Wei H , Cui L. Effect of heat acclimation pretreatment on changes of membrane lipid peroxidation, antioxidant metabolites, and ultrastructure of chloroplast in two cool-season turf grass species under heat stress. Environ. Exp. Bot. 2006;56:274285.
Yadav S.K. Cold stress tolerance mechanisms in plants. Agron. Suatain. Dev. 2010;30:515527.
Yadava P , Kaushal J , Gautam A , Parmar H , Singh I. Physiological and biochemical effect of 24-epibrassinolide on heat-stress adaptation in maize. Nat. Sci. 2016;59:171179.
Yu X , Li L , Zola J , Aluru M , Ye H , Foudree A. A brassinosteroid transcriptional network revealed by genome-wide identification of BESI target genes in Arabidopsis thaliana. Plant J. 2011;65:634646.
Yuan JS , Yong JS , Ming TW , Xu YL , Xiang G , Rong H , Jun M. Effect of seed priming in germination and seedling growth under water stress in rice. Acta Agron. Sin. 2010;36:19311940.
Yuan LB , Peng ZH , Zhi TT , Zho Z , Liu Y , Zhu Q. Brassinosteroid enhances cytokinin-induced anthocyanin biosynthesis in Arabidopsis seedlings. Biol. Plant. 2015;59:99105.
358 Yuan T , Fujioka S , Takatsuto S , Matsumoto S , Gou X , He K. BEN1, a gene encoding a dihydroflavonol 4-reductase (DFR)-like protein, regulates the levels of brassinosteroids in Arabidopsis thaliana. Plant J. 2007;51:220233.
Yueqing H , Shitou X , Yi S , Huiqun W , Weigui L , Shengying S , Langtao X. Brassinolide increases potato root growth in vitro in a dose-dependent way and alleviates salinity stress. Bio Med Res. Int. 2016; 16: 111.
Zhang F , Wang Y , Yang Y , Wu D , Wang H , Liu J. Involvement of hydrogen peroxide and nitric oxide in salt resistance in the calluses from Populus euphratica. Plant Cell Environ. 2007;7:775785.
Zhang HX , Xia Y , Wang G.P. Excess copper induces accumulation of hydrogen peroxide and increases lipid peroxidation and total activity of copper-zinc superoxide dismutase in roots of Elsholtzia haichowensis. Planta 2008;227:465475.
Zhang SS , Cai ZY , Wang X.L. The primary signaling outputs of brassinosteroids are regulated by abscisic acid signaling. Proc. Natl. Acad. Sci. USA 2009;106:45434548.
Zhu J , Liu Z , Brady EC , Otto-Bliesner BL , Marcott SA , Zhang J , Wang X , Nusbaumer J , Wong TE , Jahn A , Noone D. Investigating the direct meltwater effect in terrestrial oxygen-isotope paleoclimate records using an isotope-enabled Earth System Model. Geophys. Res. Lett. 2017;44:1250112510.

Genetic Engineering Approaches for Abiotic Stress Tolerance in Broccoli: Recent Progress

Ahmed, N. U. , Jung, H. J. , Park, J. I. , Cho, Y. G. , Hur, Y. , and Nou, I. S. 2015. Identification and expression analysis of cold and freezing stress responsive genes of Brassica oleracea. Gene 554:215223.
Ahmed, N. U. , Park, J. I. , Jung, H. J. , Lee, I. H. , Song, I. J. , Yang, S. Y. , et al. 2012. Identification and characterization of longevity assurance gene related to stress resistance in Brassica. African Journal of Biotechnology 11:1272112727.
Atkinson, N. J. , and Urwin, P. E. 2012. The interaction of plant biotic and abiotic stresses: From genes to the field. Journal of Experimental Botany 63(10):35233543.
Bale, J. S. , Masters, G. J. , Hodkinson, I. D. , Awmack, C. , Bezemer, T. M. , Brown, V. K. , et al. 2002. Herbivory in global climate change research: Direct effects of rising temperature on insect herbivores. Global Change Biology 8:116.
Bhalla, P. L. , and Singh, M. B. 2008. Agrobacterium-mediated transformation of Brassica napus and Brassica oleracea. Nature Protocols 3:181189.
Bhatnagar-Mathur, P. , Vadez, V. , and Sharma, K. K. 2008. Transgenic approaches for abiotic stress tolerance in plants: Retrospect and prospects. Plant Cell Reports 27:411424.
366 Bjorkman, T., and Pearson, K. J. 1998. High temperature arrest of inflorescence development in broccoli (Brassica oleracea L. var. italica). Journal of Experimental Botany 49:101106.
Cao, J. , and Earle, E. D. 2003. Transgene expression in broccoli (Brassica oleracea var. italica) clones propagated in vitro via leaf explants. Plant Cell Reports 21:789796.
Cardoza, V. , and Stewart, C. N. Jr. 2003. Increased Agrobacterium mediated transformation and rooting efficiencies in canola (Brassica napus L.) from hypocotyl explants. Plant Cell Reports 21:599604.
Chang, Y. M. , Liou, P. C. , and Hsiao, C. H. 1996. Anther culture of cabbage (Brassica oleracea L. var. capitata) and broccoli (B. oleracea L. var. italica). Journal of Agriculture Research in China 45:3546.
Chen, L. O. , Chin, H. L. , Kelkarc, S. M. , Chang, Y. M. , and Shawa, J. F. 2007. Transgenic broccoli (Brassica oleracea L. var. italica) with antisense chlorophyllase (BOCLH1) delays postharvest yellowing. Plant Science 174:2531.
Chen, L. O. , Hwang, J. Y. , Wang, Y. H. , Chen, Y. T. , and Shaw, J. 2004. Ethylene insensitive and post-harvest yellowing retardation in mutant ethylene response sensor gene transformed broccoli. Molecular Breeding 14:199213.
Christey, M. C. , and Earle, E. D. 1991. Regeneration of Brassica oleracea from peduncle explants. Horticulture Science 26:10691072.
Fahey, J. W. , Zhang, Y. , and Talalay, P. 1997. Broccoli sprouts: An exceptionally rich source of inducers of enzymes that protect against chemical carcinogens. Proceeding of National Academy of Sciences USA 99:1036710372.
Farzinebrahimi, R. , Taha, R. M. , Fadainasab, M. , and Mokhtar, S. 2012. In vitro plant regeneration, antioxidant and antibacterial studies on broccoli, Brassica oleracea var. italica. Pakistan Journal of Botany 44:21172122.
Feher . 1985. Sprouting broccoli. In Vegetable Crops, ed. Bose, T. K. , Kabir, J. , Maity, T. K. , Parthasarathy, V. A. , and Som, M. G. , 411419. Naya Prakash, Kolkata.
Finley, J. W. 2003. Reduction of cancer risk by consumption of selenium-enriched plants: Enrichment of broccoli with selenium increases the anticarcinogenic properties of broccoli. Journal of Medicinal Food 6:1926.
Finley, J. W. , Ip, C. , Lisk, D. J. , Davis, C. D. , Hintze, K. G. , and Whanger, P. D. 2001. Cancer-protective properties of high-selenium broccoli. Journal of Agriculture and Food Chemistry 49:26792683.
Gill, S. S. , Anjum, N. A. , Gill, R. , and Tuteja, N. 2016. Abiotic stress signaling in plantsAn overview. In Abiotic Stress Response in Plants, ed. Tuteja, N. , and Gill, S. S. , 312. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim.
Gill, S. S. , and Tuteja, N. 2010. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiology and Biochemistry 48:909930.
Henzi, M. X. , Christey, M. C. , and McNeil, D. L. 2000. Factors that influence Agrobacterium rhizogenes-mediated transformation of broccoli (Brassica oleracea L. var. italica). Plant Cell Reports 19:994999.

Hiei, Y. , Ishida, Y. , Kasaoka, K. , and Komari, T. 2006. Improved frequency of transformation in rice and maize by treatment of immature embryos with centrifugation and heat prior to infection with Agrobacterium tumefaciens. Plant Cell Tissue and Organ Culture 87:233243.

Higgins, J. D. , Newbury, H. J. , Barbara, D. J. , Muthumeenakshi, S. , and Puddephat, I. J. 2006. Production of marker-free genetically engineered broccoli with sense and antisense ACC synthase 1 and ACC oxidase 1 and 2 to extend shelf life. Molecular Breeding 17:720.

Hong, Z. J. , Yan, Z. H. , Guo, T. N. , Fang, T. Y. , Yun, Z. X. , and Xiu, L. Y. 2009. Several methods to detect the inheritance and resistance to the Diamondback Moth in transgenic Chinese cabbage. African Journal of Biotechnology 8(12):28872892.

Huang, K. , Jiashu, C. , Xiaolin, Y. , Wanzhi, Y. , Gang, L. , and Xiang, X. 2005. Plant male sterility induced by antigene CYP86MF in Brassica oleracea L. var. italica. Agriculture Science China 4:806810.

Huang, K. , Qiuyun, W. , Juncleng, L. , and Zheng, J. 2011. Optimization of plant regeneration from broccoli. African Journal of Biotechnology 10:40814085.

Kasuga, M. , Liu, Q. , Miura, S. , Yamaguchi-Shinozaki, K. , and Shinozaki, K. 1999. Improving plant drought, salt, and freezing tolerance by gene transfer of a single stress inducible transcription factor. Nature Biotechnology 17:287291.

Kaur, N. , Vyvadilova, M. , Klima, M. , and Bechyne, M. 2006. A simple procedure for mesophyll protoplast culture and plant regeneration in Brassica oleracea L. and Brassica napus L. Czech Journal of Genetics and Plant Breeding 3:103110.

Kayum, M. A. , Park, J. I. , Ahmed, N. U. , Saha, G. , Chung, M. Y. , Kang, J. G. , et al. 2016. Alfin-like transcription factor family: Characterization and expression profiling against stresses in Brassica oleracea. Acta Physiologia Plantarum 38:127.

Kayum, M. D. , Kim, H. T . , Nath, U. K. , Park, J. I. , Kho, K. H. , Cho, Y. G. , et al. 2016. Research on biotic and abiotic stress related genes exploration and prediction in Brassica rapa and B. oleracea: A review. Plant Breeding and Biotechnology 4(2):135144.

Keck, A. S. , Qiao, Q. , and Jeffery, E. H. 2003. Food matrix effects on bioactivity of broccoli-derived sulforaphane in liver and colon of f344 rats. Journal of Agriculture and Food Chemistry 51:33203327.

Kim, J. H. , and Botella, J. R. 2002. Callus induction and plant regeneration from broccoli (Brassica oleracea var. italica) for transformation. Journal of Plant Biology 45:177181.

Kreps, J. A. , Wu, Y. J. , Chang, H. S. , Zhu, T. , Wang, X. , and Harper, J. F. 2002. Transcriptome changes for Arabidopsis in response to salt, osmotic, and cold stress. Plant Physiology 130:21292141.

Kumar, P. , Gambhir, G. , Gaur, A. , and Srivastava, D. K. 2015a. Molecular analysis of genetic stability in in vitro regenerated plants of broccoli (Brassica oleracea L. var. italica). Current Science 109(8):14701475.

Kumar, P. , Gaur, A. , and Srivastava, D. K. 2015b. Morphogenic response of leaf and petiole explants of broccoli using thidiazuron. Journal of Crop Improvement 29:432446.

Kumar, P. , Gaur, A. , and Srivastava, D. K. 2017. Agrobacterium-mediated insect resistance gene (cry1Aa) transfer studies pertaining to antibiotic sensitivity on cultured tissues of broccoli (Brassica oleracia L. var. italica): An important vegetable crop. International Journal of Vegetable Science 23(6):523535. doi:10.1080/19315260.2017.1334734.

Kumar, P. , and Srivastava, D. K. 2015a. Effect of potent cytokinin thidiazuron (TDZ) on in vitro morphogenic potential of broccoli (Brassica oleracea L. var. italica), an important vegetable crop. Indian Journal of Plant Physiology 20(4):317323.

367 Kumar, P. , and Srivastava, D. K. 2015b. High frequency organogenesis in hypocotyl, cotyledon, leaf and petiole explants of broccoli (Brassica oleracea L. var. italica), an important vegetable crop. Physiology and Molecular Biology of Plants 21(2):279285.

Kumar, P. , and Srivastava, D. K. 2016a. Biotechnological advancement in genetic improvement of broccoli (Brassica oleracea L. var. italica), an important vegetable crop. Biotechnology Letters 38(7):10491063.

Kumar, P. , and Srivastava, D. K. 2016b. Biotechnological application in in vitro plant regeneration studies of Broccoli (Brassica oleracea l. var. italica), an important vegetable crop. Biotechnology Letters 38(4):561571.

Lin, H. H. , Lin, K. H. , Chen, S. C. , Shen, Y. H. , and Lo, H. F. 2015. Proteomic analysis of broccoli (Brassica oleracea) under high temperature and waterlogging stresses. Botanical Studies 56:18.

Liu, M. S. , Li, H. C. , Chang, Y. M. , Wu, M. T. , and Chen, L. F. 2011. Proteomic analysis of stress-related proteins in transgenic broccoli harboring a gene for cytokinin production during postharvest senescence. Plant Science 181:288299.

Liu, M. S. , Li, H. C. , Lai, Y. M. , Lo, H. F. , and Chen, L. F. 2013. Proteomics and transcriptomics of broccoli subjected to exogenously supplied and transgenic senescence induced cytokinin for amelioration of postharvest yellowing. Journal of Proteomics 20:133144.

Liu, T. , Song, X. , Duan, W. , Huang, Z. , Liu, G. , Li, Y. , et al. 2014. Genome-wide analysis and expression patterns of NAC transcription factor family under different developmental stages and abiotic stresses in Chinese cabbage. Plant Molecular Biology Reports 32:10411056.

Luck, J. , Spackman, M. , Freeman, A. , Trebicki, P. , Griffiths, W. , Finlay, K. , and Chakraborty, S. 2011. Climate change and diseases of food crops. Plant Pathology 60:113121.

Madgwick, J. W. , West, J. S. , White, R. P. , Semenov, M. A. , Townsend, J. A. , Turner, J. A. , et al. 2011. Impacts of climate change on wheat anthesis and fusarium ear blight in the UK. European Journal of Plant Pathology 130:117131.

Metz, T. D. , Dixit, T. R. , and Earle, E. D. 1995a. Agrobacterium tumefaciens mediated transformation of broccoli (Brassica oleracea var. italica) and cabbage (B. oleracea var. capitata). Plant Cell Reports 15:287292.

Metz, T. D. , Roush, R. T. , Tang, J. D. , Shelton, A. M. , and Earle, E. D. 1995b. Transgenic broccoli expressing a Bacillus thuringiensis insecticidal crystal protein: Implications for pest resistance management strategies. Molecular Breeding 4:309317.

Mittler, R. , and Blumwald, E. 2010. Genetic engineering for modern agriculture: Challenges and perspectives. Annual Review in Plant Biology 61:443462.

Narberhaus, F. 2010. Translational control of bacterial heat shock and virulence genes by temperature-sensing mRNAs. RNA Biology 7:8489.

Newton, A. C. , Johnson, S. N. , and Gregory, P. J. 2011. Implications of climate change for diseases, crop yields and food security. Euphytica 179:318.

Nicol, J. M. , Turner, S. J. , Coyne, D. L. , Den, N. L. , Hockland, S. , and Tahna, M. Z. 2011. Current nematode threats to world agriculture. In Genomics and Molecular Genetics of Plantnematode Interactions, ed. Jones, J. , Gheysen, G. , and Fenoll, C. , 2144. Springer, London.

Omar, S. A. , Fu, Q. T. , Chen, M. S. , Wang, G. J. , Song, S. Q. , Elsheery, N. I. , et al. 2011. Identification and expression analysis of two small heat shock protein cDNAs from developing seeds of biodiesel feedstock plant Jatropha curcas. Plant Science 181:632637.

Opabode, J. T. 2006. Agrobacterium-mediated transformation of plants: Emerging factors that influence efficiency. Biotechnology and Molecular Biology Review 1:1220.

Porter, J. R. , and Semenov, M. A. 2005. Crop responses to climatic variation. Philosophical Transactions of the Royal Society B: Biological Sciences 360:20212035.

Pucciariello, C. , Parlanti, S. , Banti, V. , Novi, G. , and Perata, P. 2012. Reactive oxygen species-driven transcription in Arabidopsis under oxygen deprivation. Plant Physiology 159(1):184196.

Puddephat, I. J. , Riggs, T. J. , and Fenning, T. M. 1996. Transformation of Brassica oleracea L.: A critical review. Molecular Breeding 2(3):185210.

Puddephat, I. J. , Robinson, H. T. , Fenning, T. M. , Barbara, D. J. , Morton, A. , and Pink, D. A. C. 2001. Recovery of phenotypically normal transgenic plants of Brassica oleracea L. var. italica upon Agrobacterium rhizogenes-mediated co-transformation and selection of transformed hairy roots by GUS assay. Molecular Breeding 7:229242.

Qin, Y. , Li, H. L. , and Guo, Y. D. 2006. High frequency embryogenesis, regeneration of broccoli (Brassica oleracea var. italica) and analysis of genetic stability by RAPD. Scientia Horticulturae 111:203208.

Rafat, A. , Aziz, M. A. , Rashid, A. A. , Abdullah, S. N. A. , Kamaladini, H. , Sirchi, M. H. T. , et al. 2010. Optimization of Agrobacterium tumefaciens-mediated transformation and shoot regeneration after co-cultivation of cabbage (Brassica oleracea subsp. capitata cv. KY Cross) with AtHSP101 gene. Scientia Horticulture 124:18.

Ramakrishna, A. , and Ravishankar, G. A. 2011. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signaling and Behavior 6:17201731.

Ramakrishna, A. , and Ravishankar, G. A. 2013. Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In Climate Change and Plant Abiotic Stress Tolerance, 705726, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim.

Ravanfar, S. A. , and Aziz, M. A. 2014. Shoot tip regeneration and optimization of Agrobacterium tumefaciens-mediated transformation of Broccoli (Brassica oleracea var. italica) cv. Green Marvel. Plant Biotechnology 9:2736.

Ravanfar, S. A. , Aziz, M. A. , Kadir, M. A. , Rashid, A. A. , and Haddadi, F. 2011. In vitro shoot regeneration and acclimatization of Brassica oleracea var. italica cv. Green marvel. African Journal of Biotechnology 10:56145619 .

Ravanfar, S. A. , Aziz, M. A. , Kadir, M. A. , Rashid, A. A. , and Sirchi, M. H. T. 2009. Plant regeneration of Brassica oleracea var. italica (broccoli) cv. Green marvel was affected by plant growth regulators. African Journal of Biotechnology 8:25232528.

Ravanfar, S. A. , Aziz, M. A. , Rashid, A. A. , and Shahida, S. 2014. In vitro adventitious shoot regeneration from cotyledon explant of Brassica oleracea subsp. italica and Brassica oleracia subsp. capitata using TDZ and NAA. Pakistan Journal of Botany 46:329335.

368 Rizhsky, L. , Liang, H. J. , and Mittler, R. 2002. The combined effect of drought stress and heat shock on gene expression in tobacco. Plant Physiology 130:11431151.

Robertson, D. , and Earle, E. D. 1986. Plant regeneration from leaf protoplasts of Brassica oleracea L. var. italica. Plant Cell Reports 5:6164.

Saha, G. , Park, J. I. , Jung, H. J. , Ahmed, N. U. , Kayum, M. A. , Kang, J. G. , et al. 2015. Molecular characterization of BZR transcription factor family and abiotic stress induced expression profiling in Brassica rapa. Plant Physiology and Biochemistry 92:92104.

Seki, M. , Narusaka, M. , Ishida, J. , Nanjo, T. , Fujita, M. , Oono, Y. , et al. 2002. Monitoring the expression profiles of 7000 Arabidopsis genes under drought, cold and high-salinity stresses using a full-length cDNA microarray. The Plant Journal 31:279292.

Srivastava, D. K. , Kumar, P. , Sharma, S. , Gaur, A. , and Gambhir, G. 2016. Genetic engineering for insect resistance in economically important vegetable crops. In Plant Tissue Culture: Propagation, Conservation and Crop, ed. Ahmad, N. , and Anis, M. , 343378, Springer Publishing House, Singapore.

Suri, S. S. , Saini, A. R. K. , and Ramawat, K. G. 2005. High Frequency Regeneration and Agrobacterium tumefaciens-mediated Transformation of Broccoli (Brassica oleracea var. italica). European Journal of Horticulture Science 70:7178.

Takeda, S. , and Matsuoka, M. 2008. Genetic approaches to crop improvement: Responding to environmental and population changes. Nature Reviews Genetics 9:444457.

Tian, Y. , Tian, Y. , Luo, X. , Zhou, T. , Huang, Z. , Liu, Y. , et al. 2014. Identification and characterization of microRNAs related to salt stress in broccoli, using high-throughput sequencing and bioinformatics analysis. BMC Plant Biology 14:226.

Torok, Z. , Goloubinoff, P. , Horvath, I. , Tsvetkova, N. M. , Glatz, A. , Balogh, G. , et al. 2001 . Synechocystis HSP17 is an amphitropic protein that stabilizes heat-stressed membranes and binds denatured proteins for subsequent chaperone mediated refolding. Proceeding of National of Academy Science USA 98:30983103.

Umezawa, T. , Fujita, M. , Fujita, Y. , Yamaguchi-Shinozaki, K. , and Shinozaki, K. 2006. Engineering drought tolerance in plants: Discovering and tailoring genes to unlock the future. Current Opinion in Biotechnology 17:113122.

Vallejo, F. , Garcia-viguera, C. , and Tomas-barberan, F. A. 2003. Changes in broccoli (Brassica oleracea var. italica) health promoting compounds with inflorescence development. Journal of Agriculture and Food Chemistry 51:37763782.

Vasudevan, A. , Selvaraj, N. , Ganapathi, A. , and Choi, C. W. 2007. Agrobacterium-mediated genetic transformation in cucumber (Cucumis sativus L.). American Journal of Biotechnology and Biochemistry 3:2432.

Vinocur, B. , and Altman, A. 2005. Recent advances in engineering plant tolerance to abiotic stress: Achievements and limitations. Current Opinion in Biotechnology 16:123132.

Wang, Z. , Tang, J. , Hu, R. , Wu, P. , Hou, X. L. , Song, X.M. , et al. 2015. Genome-wide analysis of the R2R3-MYB transcription factor genes in Chinese cabbage (Brassica rapa ssp. pekinensis) reveals their stress and hormone responsive patterns. BMC Genomics 16:17.

Waters, E. R. , Lee, G. J. , and Vierling, E. 1996. Evolution, structure and function of the small heat shock proteins in plants. Journal of Experimental Botany 47:325338.

Xing, Y. , Yang, Q. , Ji, Q. , Luo, Y. , Zhang, Y. , Gu, K. , et al. 2007. Optimization of Agrobacterium-mediated transformation parameters for sweet potato embryogenic callus using -glucuronidase (GUS) as a reporter. African Journal of Biotechnology 6:25782584.

Young, J. M. , Kerr, A. , and Sawada, H. 2003. Genus Agrobacterium. In Bergeys Manual of Systematic Bacteriology, 2nd ed. Springer, New York.

Zhang, Y. S. , Talalay, P. , Cho, C. G. , and Posner, G. 1992. A major inducer of anticarcinogenic protective enzymes from broccoli: Isolation and elucidation of structure. Proceeding of National Academy of Sciences USA 89:23992403.

Zhong, Z. X. , and Li, X. 1993. Plant regeneration from hypocotyl protoplasts culture of Brasscia oleracea L. var. italica. Acta Agriculture Shanghai 9:1318.

Impact of Abiotic Stresses on Metabolic Adaptation in Opium Poppy (Papaver somniferum L.)

Alagoz Y , Gurkok T , Zhang B , Unver T. Manipulating the biosynthesis of bioactive compound alkaloids for next-generation metabolic engineering in opium poppy using CRISPR-Cas 9 genome editing technology. Scientific Reports 2016;6:30910.

Allen RS , Millgate AG , Chitty JA , Thisleton J , Miller JA , Fist AJ , et al. RNAi-mediated replacement of morphine with the nonnarcotic alkaloid reticuline in opium poppy. Nature Biotechnology 2004;22(12):15591566.

Angelova S , Buchheim M , Frowitter D , Schierhorn A , Roos W. Overproduction of alkaloid phytoalexins in California poppy cells is associated with the co-expression of biosynthetic and stress-protective enzymes. Molecular Plant 2010;3(5):927 927.

Aroca R , Vernieri P , Ruiz-Lozano J.M. Mycorrhizal and non-mycorrhizal Lactuca sativa plants exhibit contrasting responses to exogenous ABA during drought stress and recovery. Journal of Experimental Botany 2008;59(8):20292041.

G A Beaudoin , Facchini P.J. Benzylisoquinoline alkaloid biosynthesis in opium poppy. Planta 2014;240(1):1932.

Boke H , Ozhuner E , Turktas M , Parmaksiz I , Ozcan S , Unver T. Regulation of the alkaloid biosynthesis by miRNA in opium poppy. Plant Biotechnology Journal 2015;13(3):409420.

Bowne JB , Erwin TA , Juttner J , Schnurbusch T , Langridge P , Bacic A , et al. Drought responses of leaf tissues from wheat cultivars of differing drought tolerance at the metabolite level. Molecular Plant 2012;5(2):418429.

Bricchi I , Bertea CM , Occhipinti A , Paponov IA , Maffei M.E. Dynamics of membrane potential variation and gene expression induced by Spodoptera littoralis, Myzus persicae, and Pseudomonas syringae in Arabidopsis. PLoS One 2012;7(10):e46673.

Cheng M-C , Liao P-M , Kuo W-W , Lin T-P. The Arabidopsis ETHYLENE RESPONSE FACTOR1 regulates abiotic stress-responsive gene expression by binding to different cis-acting elements in response to different stress signals. Plant Physiology 2013;162(3):15661582.

Cheong YH , Chang H-S , Gupta R , Wang X , Zhu T , Luan S. Transcriptional profiling reveals novel interactions between wounding, pathogen, abiotic stress, and hormonal responses in Arabidopsis. Plant Physiology 2002;129(2):661677.

Christenhusz MJ , Byng J.W. The number of known plants species in the world and its annual increase. Phytotaxa 2016;261(3):201217.

Dang Ttt , Facchini P.J. Characterization of three O-Methyltransferases involved in noscapine biosynthesis in opium poppy. Plant Physiology 2012;159(2):618631. doi:10.1104/pp.112.194886

de Abreu IN , Mazzafera P. Effect of water and temperature stress on the content of active constituents of Hypericum brasiliense Choisy. Plant Physiology and Biochemistry 2005;43(3):241248.

378 Desgagn-Penix I , Facchini P.J. Systematic silencing of benzylisoquinoline alkaloid biosynthetic genes reveals the major route to papaverine in opium poppy. The Plant Journal 2012;72(2):331344.

Erxleben A , Gessler A , Vervliet-Scheebaum M , Reski R. Metabolite profiling of the moss Physcomitrella patens reveals evolutionary conservation of osmoprotective substances. Plant Cell Reports 2012;31(2):427436.

Facchini PJ , Park S-U. Developmental and inducible accumulation of gene transcripts involved in alkaloid biosynthesis in opium poppy. Phytochemistry 2003;64(1):177186.

Fraire-Velzquez S , Balderas-Hernndez V.E. Abiotic Stress in Plants and Metabolic Responses. INTECH Open Access Publisher, Croatia, 2013; pp. 2548.

Gechev TS , Benina M , Obata T , Tohge T , Sujeeth N , Minkov I , et al. Molecular mechanisms of desiccation tolerance in the resurrection glacial relic Haberlea rhodopensis. Cellular and Molecular Life Sciences 2013;70(4):689709.

Golldack D , Lking I , Yang O. Plant tolerance to drought and salinity: Stress regulating transcription factors and their functional significance in the cellular transcriptional network. Plant Cell Reports 2011;30(8):1383 1391.

Gmez-Galera S , Pelacho AM , Gen A , Capell T , Christou P. The genetic manipulation of medicinal and aromatic plants. Plant Cell Reports 2007;26(10):16891715.

Gurkok T , Turktas M , Parmaksiz I , Unver T. Transcriptome profiling of alkaloid biosynthesis in elicitor induced opium poppy. Plant Molecular Biology Reporter 2015;33(3):673688.

Hawrylak-Nowak B. Changes in anthocyanin content as indicator of maize sensitivity to selenium. Journal of Plant Nutrition 2008;31(7):12321242.

Huang F-C , Kutchan T.M. Distribution of morphinan and benzo [c] phenanthridine alkaloid gene transcript accumulation in Papaver somniferum. Phytochemistry 2000;53(5):555564.

Hubert DA , Tornero P , Belkhadir Y , Krishna P , Takahashi A , Shirasu K , et al. Cytosolic HSP90 associates with and modulates the Arabidopsis RPM1 disease resistance protein. The EMBO Journal 2003;22(21):56795689. doi:10.1093/emboj/cdg547.

Infante F , Dominguez E , Trujillo D , Luna A. Metal contamination in illicit samples of heroin. Journal of Forensic Science 1999;44(1):110113.

Inui T , Tamura K-i , Fujii N , Morishige T , Sato F. Overexpression of Coptis japonica norcoclaurine 6-O-methyltransferase overcomes the rate-limiting step in benzylisoquinoline alkaloid biosynthesis in cultured Eschscholzia californica. Plant and Cell Physiology 2007;48(2):252262.

Jiang W , Wu J , Zhang Y , Yin L , Lu J. Isolation of a WRKY30 gene from Muscadinia rotundifolia (Michx) and validation of its function under biotic and abiotic stresses. Protoplasma 2015;252(5):13611374.

Kar R.K. Plant responses to water stress: Role of reactive oxygen species. Plant Signaling and Behavior 2011;6(11):17411745.

Kim JK , Bamba T , Harada K , Fukusaki E , Kobayashi A. Time-course metabolic profiling in Arabidopsis thaliana cell cultures after salt stress treatment. Journal of Experimental Botany 2007;58(3):415424.

Lachman J , Hejtmankova A , Miholova D , Kolihov D , Tluka P. Relations among alkaloids, cadmium and zinc contents in opium poppy (Papaver somniferum L.). Plant Soil and Environment 2006;52(6):282.

Lehmann M , Schwarzlnder M , Obata T , Sirikantaramas S , Burow M , Olsen CE , et al. The metabolic response of Arab idopsis roots to oxidative stress is distinct from that of heterotrophic cells in culture and highlights a complex relationship between the levels of transcripts, metabolites, and flux. Molecular Plant 2009;2(3):390406.

Leonard E , Runguphan W , OConnor S , Prather K.J. Opportunities in metabolic engineering to facilitate scalable alkaloid production. Nature Chemical Biology 2009;5(5):292300.

Maldonado-Bonilla L.D. Composition and function of P bodies in Arabidopsis thaliana. Frontiers in Plant Science 2014;5:201.

Mishra S , Phukan UJ , Tripathi V , Singh DK , Luqman S , Shukla R.K. PsAP2 an AP2/ERF family transcription factor from Papaver somniferum enhances abiotic and biotic stress tolerance in transgenic tobacco. Plant Molecular Biology 2015;89(12):173186.

Mishra S , Triptahi V , Singh S , Phukan UJ , Gupta M , Shanker K , et al. Wound induced tanscriptional regulation of benzylisoquinoline pathway and characterization of wound inducible PsWRKY transcription factor from Papaver somniferum. PLoS One 2013;8(1):e52784.

Mller IM , Sweetlove L.J. ROS signallingspecificity is required. Trends in Plant Science 2010;15(7):370374.

Morimoto S , Suemori K , Moriwaki J , Taura F , Tanaka H , Aso M , et al. Morphine metabolism in the opium poppy and its possible physiological function biochemical characterization of the morphine metabolite, bismorphine. Journal of Biological Chemistry 2001;276(41):3817938184.

Park JM , Park C-J , Lee S-B , Ham B-K , Shin R , Paek K-H. Overexpression of the tobacco Tsi1 gene encoding an EREBP/AP2type transcription factor enhances resistance against pathogen attack and osmotic stress in tobacco. The Plant Cell 2001;13(5):10351046.

Ramakrishna A , Ravishankar G.A. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signaling and Behavior 2011;6:17201731.

Ramakrishna A , Ravishankar G.A. Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Climate Change and Plant Abiotic Stress Tolerance, Tuteja, N., and Gill, S. S.(ed.). Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2013; pp. 705726.

Rassow J , Mohrs K , Koidl S , Barthelmess IB , Pfanner N , Tropschug M. Cyclophilin 20is involved in mitochondrial protein folding in cooperation with molecular chaperones Hsp70 and Hsp60. Molecular and Cellular Biology 1995;15(5):26542662.

Rastogi A , Mishra BK , Shukla S. Opium poppy: An ancient medicinal plant. In: Breeding of Field Crops, Bharadwaj DN (ed.). Agrobios Publications, Jodhpur, India, 2012; pp. 865903.

Rodziewicz P , Swarcewicz B , Chmielewska K , Wojakowska A , Stobiecki M. Influence of abiotic stresses on plant proteome and metabolome changes. Acta Physiologiae Plantarum 2014;36(1):119.

Romano PG , Horton P , Gray J.E. The Arabidopsis cyclophilin gene family. Plant Physiology. 2004;134(4):12681282.

Shukla RK , Raha S , Tripathi V , Chattopadhyay D. Expression of CAP2, an APETALA2-family transcription factor from chickpea, enhances growth and tolerance to dehydration and salt stress in transgenic tobacco. Plant Physiology 2006;142(1):113123.

379 Sicher RC , Barnaby J.Y. Impact of carbon dioxide enrichment on the responses of maize leaf transcripts and metabolites to water stress. Physiologia Plantarum 2012;144(3):238253.

Silvente S , Sobolev AP , Lara M. Metabolite adjustments in drought tolerant and sensitive soybean genotypes in response to water stress. PLoS One 2012;7(6):e38554.

Suttipanta N , Pattanaik S , Kulshrestha M , Patra B , Singh SK , Yuan L. The transcription factor CrWRKY1 positively regulates the terpenoid indole alkaloid biosynthesis in Catharanthus roseus. Plant Physiology 2011;157(4):20812093.

Szab B , Tyihk E , Szab G , Botz L. Mycotoxin and drought stress induced change of alkaloid content of Papaver somniferum plantlets. Acta Botanica Hungarica 2003;45(34):409417.

Tripathi P , Rabara RC , Rushton P.J. A systems biology perspective on the role of WRKY transcription factors in drought responses in plants. Planta 2014;239(2):255266.

Veeranagamallaiah G , Jyothsnakumari G , Thippeswamy M , Reddy PCO , Surabhi G-K , Sriranganayakulu G , et al. Proteomic analysis of salt stress responses in foxtail millet (Setaria italica L. cv. Prasad) seedlings. Plant Science 2008;175(5):631641.

Verma N , Shukla, S. Impact of various factors responsible for fluctuation in plant secondary metabolite. Journal of Applied Research on Medicinal and Aromatic Plants 2015;2:105113.

Viehweger K , Schwartze W , Schumann B , Lein W , Roos W. The G protein controls a pH-dependent signal path to the induction of phytoalexin biosynthesis in Eschscholzia californica. The Plant Cell 2006;18(6):15101523.

Vogel M , Lawson M , Sippl W , Conrad U , Roos W. Sanguinarine reductase -structure and mechanism of an enzyme of alkaloid detoxication. Journal of Biological Chemistry 2010;285(24):jbc.M109.088989.

Weid M , Ziegler J , Kutchan T.M. The roles of latex and the vascular bundle in morphine biosynthesis in the opium poppy, Papaver somniferum. Proceedings of the National Academy of Sciences of the United States of America 2004;101(38):1395713962.

Weiss D , Baumert A , Vogel M , Roos W. Sanguinarine reductase, a key enzyme of benzophenanthridine detoxification. Plant, Cell and Environment 2006;29(2):291302.

Wijekoon CP , Facchini P.J. Systematic knockdown of morphine pathway enzymes in opium poppy using virusinduced gene silencing. The Plant Journal 2012;69(6):10521063.

Zhang J , Zhang Y , Du Y , Chen S , Tang H. Dynamic metabonomic responses of tobacco (Nicotiana tabacum) plants to salt stress. Journal of Proteome Research 2011;10(4):19041914.

Zhu X , Qi L , Liu X , Cai S , Xu H , Huang R , et al. The wheat ethylene response factor transcription factor pathogen-induced ERF1 mediates host responses to both the necrotrophic pathogen Rhizoctonia cerealis and freezing stresses. Plant Physiology 2014;164(3):14991514.

Zulak KG , Lippert DN , Kuzyk MA , Domanski D , Chou T , Borchers CH , et al. Targeted proteomics using selected reaction monitoring reveals the induction of specific terpene synthases in a multilevel study of methyl jasmonatetreated Norway spruce (Picea abies). The Plant Journal 2009;60(6):10151030.

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Abassi NA , Kushad MM , Endress A.G. Active oxygen-scavenging enzymes activities in developing apple flowers and fruits. Sci. Hort. 1998; 74: 183194.

Abdi G , Hedayat M , Khush-Khui M. Development of NaCl-tolerant line in Tanacetum cinerariaefolium (Trevir.) Schultz-Bip. through shoot organogenesis of selected callus line. J. Biol. Environ. Sci. 2011; 5(15): 111119.

Ahmad R , Hussain J , Jamil M , Kim MD , Kwak SS , Maroof M , Shah1 el-Hendawy SE, Al-Suhaibani NA, Rehman SU. Glycinebetaine synthesizing transgenic potato plants exhibit enhanced tolerance to salt and cold stresses. Pak. J. Bot. 2014; 46(6): 19871993.

Ahmad R , Kim MD , Back KH , Kim HS , Lee HS , Kwon SY , Murata N , Chung WI , Kwak S.S. Stress-induced expression of choline oxidase in potato plant chloroplasts confers enhanced tolerance to oxidative, salt, and drought stresses. Plant Cell Rep. 2008; 27: 687698.

Ahmad MSA , Ashraf M , Ali Q. Soil salinity as a selection pressure is a key determinant for the evolution of salt tolerance in Blue Panicgrass (Panicum antidotale Retz.). Flora (Jena). 2010; 205 (1): 3745.

Ahmad P , Prasad M.N.V. (2004). Abiotic stress responses in plants. J. Plant Physiol. 168: 807815.

Alvarez I , Tomaro LM , Bernavides PM. Changes in polyamines, proline and ethylene in sunflower calluses treated with NaCl. Plant Cell Tissue Organ Cult. 2003; 74(1): 5159.

Ansari SR , Frooqi AHA , Sharma S. (1998). Interspecific variation in sodium and potassium ion accumulation and essential oil metabolism in three Cymbopogon species raised under sodium chloride stress. J. Essen. Oil Res. 10: 413418.

Aqeel-Ahmad MS , Javed F , Ashraf M. Iso-osmotic effect of NaCl and PEG on growth, cations and free proline accumulation in callus tissue of two indica rice (Oryza sativa L.) genotypes. J. Plant Growth Regul. 2007; 53: 5363.

Ashraf M. Inducing drought tolerance in plants: recent advances. Biotechnol. Adv. 2010; 28: 169183.

Ashraf M , Athar HR , Harris PJC , Kwon T.R. Some prospective strategies for improving crop salt tolerance. Adv. Agron. 2008; 97: 45110.

Ashraf M , Foolad M.R. Roles of glycinebetaine and proline in improving plant abiotic stress resistance. Environ. Exp. Bot. 2007; 59: 206216.

Ashraf M , Harris P.J.C. Potential biochemical indicators of salinity tolerance in plants. Plant Sci. 2004; 166(1): 316.

Bakhsh A , Rao AQ , Shahid AA , Husnain T , Riazuddin S. Insect resistance and risk assessment studies in advance lines of Bt cotton harboring Cry1Ac and Cry2A genes. AEJAES. 2009; 6: 111.

Banu MNA , Hoque MA , Watanabe-Sugimoto M , Matsuoka K , Nakamura Y , Yasuaki S , Murata Y. Proline and glycinebetaine induce antioxid ant defense gene expression and suppress cell death in cultured tobacco cells unde r salt stress. J. Plant Physiol. 2009; 166: 146 156.

Barakat MN , Abdel-Latif, T.H. In vitro selection of wheat callus tolerance high levels of salt and plant regeneration. Euphytica 1996; 91: 127140.

Bartels D , Sunkar R. Drought and salt tolerance in plants. Crit. Rev. Plant Sci. 2005; 24: 2358.

Basu S , Gangopadhyay G , Mukherjee B.B. Salt tolerance in rice in vitro: implication of accumulation of Na+, K+ and proline. Plant Cell Tissue Organ Cult. 2002; 69: 5564.

Benavides PM , Marconi LP , Gallego MS , Comba EM , Tomaro L.M. Relationship between antioxidant defense systems and salt-tolerance in Solanum tuberosum. Aust. J. Plant Physiol. 2000; 27: 273278.

Bhaskaran S , Smith RH , Newton R.J. Physiological changes in cultured Sorgham cells in response to induced water stress 1. Free proline. Plant Physiol. 1985; 79: 239248.
Binh DQ , Heszky LE , Gyulai G , Csillag A. Plant regeneration of NaCl-pretreated cells from long-term suspension culture of rice (Oryza sativa L.) in high saline conditions. Plant Cell Tissue Organ Cult. 1992; 29: 7582.
Bor M , Ozdemir F , Turkan I. The effect of salt stress on lipid peroxidation and antioxidants in leaves of sugar beet (Beta vulgaris L.) and wild beet (Beta maritima L.). Plant Sci. 2003; 16: 7784.
Borsani O , Valpuesta V , Botella M.A. Developing salt tolerant plants in a new century: a molecular biology approach. Plant Cell Tissue Organ Cult. 2003; 73: 101115.
Boyer J.S. Plant productivity and environment. Science 1982, 218, 443448.
Boyer J.S. , and Knipling E.B. Isopiestic technique for measuring leaf water potentials with a thermocouple psychrometer. Proc Natl Acad Sci USA 1965, 54, 10441051.
386 Bracci T , Minnocci A , Sebastiani L. In vitro olive (Olea europaea L.) cvs Frantoio and Moraiolo microshoot tolerance to NaCl. Plant Biosyst. 2008; 142: 563571.
Cano EA , Perez-Alfocea F , Moreno V , Caro M , Bolarin M.C. Evaluation of salt tolerance in cultivated and wild tomato species through in vitro shoot apex culture. Plant Cell Tissue Organ Cult. 1998; 53: 1926.
Cerekovic N. , Fatnassi N. , Santino A. , Poltronieri P. Differences in physiological, biochemical, and molecular mechanisms of water stress tolerance in chickpea varieties. Chapter 6. In: Approaches in Enhancing Abiotic Stress Tolerance to Plants (Hasanuzzaman M. , Fujita M. , Oku H. , Islam T. ; Eds). Taylor and Francis, CRC in press, 2019. Catalog n. K345347.
Chandler SF , Vasil I.K. Selection and characterization of NaC1 tolerant cells from embryogenic cultures of Pennisetam purpureum Schum. (Napir grass). Plant Sci. Lett. 1984; 37: 157164.
Chaudhary MT , Merrett MJ , Wainwright S.J. Growth, ion content and proline accumulation in NaCl-selected and non-selected cell lines of lucerne cultured on sodium and potassium salts. Plant Sci. 1997; 127: 7179.
Chen R , Gyokusen K , Saito A. Selection , regeneration and protein profile characteristics of NaCl-Tolerant callus of Robinia pseudoacaia L. J. For. Res. 2001; 6: 4348.
Chen WP , Li PH , Chen T.H.H. Glycine betaine increases chilling tolerance and reduces chilling-induced lipid peroxidation in Zea mays L. Plant Cell Environment 2000; 23: 609618.
Chen Y , Zahavi E , Barak P , Ummiel N. Effects of salinity stresses on tobacco. I. The growth of N. tabacum callus cultures under seawater, NaCl, and mannitol stresses. Z. Pflanzenphysiol. 1980; 98: 141153.
Cossett DR , Banks SW , Millhollon EP , Lucas M.C. Antioxidant response to NaCl stress in a control and an NaCI-tolerant cotton cell line grown in the presence of paraquat, buthionine sulfoximine, and exogenous glutathione. Plant Physiol. 1996; 11(2): 803809.
Coughlan SJ , Heber U. The role of glycine betaine in the protection of spinach thylakoids against freezing stress. Planta. 1982; 156: 6269.
Croteau R , Kutchan T , Lewis N. (2000) Natural products (secondary metabolites). In: Biochemistry and Molecular Biology of Plants, B Buchanan , W Gruissem , R Joneas , (eds.). American Society of Plant Biologists, Rockville, MD, pp. 12501268.
Davenport SB , Gallego SM , Benavides MP , Tomaro M.L. Behavior of antioxidant defense system in the adaptive response to salt stress in Helianthus annuus L. cells. J. Plant Growth Regul. 2003; 40: 8188.
De Ronde JA , Cress WA , Kruger GHJ , Strasser RJ , VanStaden J. Photosynthetic response of transgenic soybean plants, containing an Arabidopsis P5VR gene, during heat and drought stress. Plant Physiol. 2004; 161: 12111224.
Demiral T , Turkan I. Comparative lipid peroxidation, antioxidant defense systems and proline content in roots of two rice cultivars differing in salt tolerance. Environ. Exp. Bot. 2005; 53: 247257.
Deshnium P , Gombos Z , Nishiyama Y , Murata N. The action in vivo of glycine betaine in enhancement of tolerance of Synechococcus sp. strain PCC 7942 to low temperature. J. Bacteriol. 1997; 179, 339344.
Dita, MA , Rispai N , Prats E , Rubiales D , Singh K.B. Biotechnology approaches to overcome biotic and abiotic stress constraints in legumes. Euphytica 2006; 147: 124.
Dix P.J. The role of mutant cell lines in studies on environmental stress tolerance: an assessment. Plant J. 1993; 3: 309313.
Dix PJ , Pearce R.S. Proline accumulation in NaCI resistant and sensitive cell lines of Nicotiana sylvestris. Z. Pflanzenphysiol. 1981; 102: 243248.
El Sayed H , El Sayed A. Isolation and characterization of NaCl resistant callus culture of field pea (Pisum sativum, L.) to salinity. Agric. Biol. J. N. Am. 2011; 2(6): 964973.
Fatima S , Farooqi AHA , Sangwan R.S. (2006) Water stress mediated modulation in essential oil, proline and polypeptide profile in palmarosa and citronella java. In: Physiology and Molecular Biology of Plants. Lucknow, India: Central Institue of Medicinal and Aromatic Plants, CIMAP.
Foyer CH , Lelandais M , Galap C , Kunert K.J. Effect of elevated cytosolic glutathione reductase activity on the cellular glutathione pool and photosynthesis in leaves under normal and stress conditions. Plant Physiol. 1991; 97: 863872.
Foyer CH , Noctor G. Oxidant and antioxidant signalling in plants: a reevaluation of the concept of oxidative stress in a physiological context. Plant Cell Environ. 2005; 28: 10561071.
Gandonou CB , Errabii T , Abrini J , Idaomar M , Senhaji N.S. Selection of callus cultures of sugarcane (Saccharum sp.) tolerant to NaCl and their response to salt tolerance. Plant Cell Tissue Organ Cult. 2006; 87: 916.
Gao X , Yang D , Cao D , Ao M , Sui X , Wang Q , Kimatu JN , Wang L. In vitro micropropagation of Freesia hybrida and the assessment of genetic and epigenetic stability in regenerated plantlets. J. Plant Growth Regul. 2010; 29: 257267.
Gaspar T , Penel C , Hagega D , Greppin H. Peroxidases in plant growth, differentiation and development processes. In: Biochemical, Molecular and Physiological Aspects of Plant Peroxidases (eds. J. Lobarzewsky , H. Greppin , C. Penel , and T.h. Gaspar). University of Geneve, Switzerland, 1991, pp. 249280.
Ghanti SKK , Sujata KG , Vijay Kumar BM, Karba NN, Reddy KJ, Srinath Rao M, Kavi Kishor PB. Heterologous expression of P5CS gene in chickpea enhances salt tolerance without affecting yield. Biol. Plant. 2011; 55 (4): 634640.
Gill SS , Tuteja N. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol. Biochem. 2010; 48: 909930.
Gu R , Liu Q , Pie D , Jiang X. Understanding saline and osmotic tolerance of Populus euphratica suspended cells. Plant Cell Tissue Organ Cult. 2004; 78: 261265.
Gubis JR , Vankova V , Cervena M , Dragunova M , Hudcovicova T , Dokupil L , Jurekova Z. Transformed tobacco plants with increased tolerance to drought. S. Afr. J. Bot. 2007; 73(4): 505511.
Guo WL , Wu R , Zhang YF , Liu XM , Wang HY , Gong L , Zhang ZH , Liu B. Tissue culture-induced locus-specific alteration in DNA methylation and its correlation with genetic variation in Codonopsis lanceolata Benth. et Hook. f. Plant Cell Rep. 2007; 26: 12971307.
Han KH , Hwang C.H. Salt tolerance enhanced by transformation of a P5CS gene in carrot. J. Plant Biotechnol. 2003; 5: 149153.
Harinasut P , Poonsopa D , Roengmongkol K , Charoensataporn R. Salinity effects on antioxidant enzymes in mulberry cultivar. Sci. Asia 2003; 29: 109113.
Hasegawa PM , Bressan RA , Nelson DE , Samaras Y , Rhodes D. Tissue culture in the improvement of salt tolerance in plants. In: AR Yeo and TJ Flowers (eds) Monographs on Theoretical and Applied Genetics: Breeding Plants with Resistance to Problem Soils, p 83.

1994; Springer-Verlag, Berlin.

387 Hasegawa PM , Bressan RA , Zhu JK , Bohnert H.J. Plant cellular and molecular responses to high salinity. Annu. Rev. Plant Physiol. Plant Mol. Biol. 2000; 51: 463499.

He C , Yang A , Zhang W , Gao Q , Zhang J. Improved salt tolerance of transgenic wheat by introducing betA gene for glycine betaine synthesis. Plant Cell Tissue Organ Cult. 2010; 101: 6578.

Hossain Z , Mandal AK , Datta SK , Biswas, A.K. Development of NaCl tolerant line in Chrysanthemum morifolium Ramat. through shoot organogenesis of selected callus line. J. Biotechnol. 2007; 129: 658667.

Jain M. Tissue culture-derived variation in crop improvement. Euphytica 2001; 118: 153166.

Jaiswal R , Singh N.P. Plant regeneration from NaCl tolerant callus/cell lines of chickpea. ICPN 2001; 8: 2123.

Jones RG , Storey R. Betaines . The unusually strong stabilizing effect of glycine betaine on the structure and function of the oxygen-evolving PSII comp. In: Paleg LG and Aspinal D (eds) The Physiology and Biochemistry of Draught Resistance in Plants, pp 171204. 1981; Academic Press, Sydney, Australia.

Karadimova M , Djambova G. Increased NaCl-tolerance in wheat (Triticum aestivum L. and T. durum desf.) through in vitro selection. In Vitro Cell Dev. Biol. Plant 1993; 29: 180182.

Kavi Kishore PB , Hong Z , Miao G , Hu CAA , Verma D.P.S. Over expression of Pyrroline 5 carboxylate synthetase increases proline over production and confers osmotolerance in transgenic plants. Plant Physiol. 1995; 108: 13871394.

Khan A , Iqbal I , Shah A , Humera N , Farooq A , Ibrahim M. Alleviation of adverse effects of salt stress in brassica (Brassica campestris) by pre-sowing seed treatment with ascorbic acid. AEJAES. 2010; 7: 557560.

Kumar V , Sharma D.K. Isolation and characterization of sodium chloride resistantcallus culture of Vigna radiata (L.) Wilczek var. radiata. J. Exp. Bot. 1989; 40: 143147.

Larkin PJ , Scowcroft S.C. Somaclonal variation A novel source of variability from cell culture for plant improvement. Theor. Appl. Genet. 1981; 60: 197214.

Li M , Lin X , Li H , Pan X , Wu G . Overexpression of AtNHX5 improves tolerance to both salt and water stress in rice (Oryza sativa L.). Plant Cell Tissue Organ Cult. 2011; 107(2): 283293.

Li X , Yu X , Wang N , Feng Q , Dong Z , Liu L , Shen J , Liu B. Genetic and epigenetic instabilities induced by tissue culture in wild barley (Hordeum brevisubulatum (Trin.) Link). Plant Cell Tissue Organ Cult. 2007; 90: 153168.

Lin CC , Hsu YT , Kao C.H. The effect of NaCl on proline accumulation in rice leaves. J. Plant Growth Regul. 2002; 36: 275285.

Lutts S , Almansouri M , Kinet J.M. Salinity and water stress have contrasting effects on the relationship between growth and cell viability during and after stress exposure in durum wheat callus. Plant Sci. 2004; 167: 918.

Mansour M.M.F. Nitrogen containing compounds and adaptation of plants to salinity stress. Biol. Plant 2000; 43: 491500.

McCue KF , Hanson A.D. Drought and salt tolerance: towards understanding and application. Trend Biotechnol. 1990; 8: 358362.

Mc-Hughen A , Swartz M. A tissue culture derived salt-tolerant line of flax (Linum usitatissimum). Plant Physiol. 1984; 117: 109118.

Miki Y , Hashiba M , Hisajima S. Establishment of salt stress tolerant rice plants through step-up NaCl treatment in vitro. Biol. Plant. 2001; 44: 391395.

Mohamed MAH , Harris PJC , Henderson J . In vitro selection and characterization of a drought tolerant clone of Tagetes minuta. Plant Sci. 2000; 159: 213222.

Mohanty A , Kathuria H , Ferjani A , Sakamoto A , Mohanty P , Murata N , Tyagi A. Transgenics of an elite rice variety pusa basmati 1 harbouring the codA gene are highly tolerant to salt stress. Theor. Appl. Genet. 2002; 106: 51 51.

Mondal TK , Kundu PK , Ahuja P.S. Gene silencing: a problem in transgenic research. Curr. Sci. 1997; 72: 699700.

Munir N , Aftab F. Changes in activities of antioxidant enzymes in response to NaCl stress in callus cultures and regenerated plants of sugarcane. J. Anim. Plant Sci. 2013; 23(1): 203209.

Musa Y. The use of polyethylene glycol (PEG) as selection agent of callus and plantlets of some sugarcane varieties for drought tolerance. J. Agrivigor. 2011; 10(2): 130140.

Nabors MW , Gibbs GE , Bernstein CS , Meis M.E. NaCl-tolerant tobacco plants from cultured cells. Z. Pflanzenphysiol. 1980; 97: 1317.

Naik GR , Harinath K. Redifferentiation of NaCl tolerant sugarcane plants from callus derived resistant lines. Curr. Sci. 1988; 57(8): 432433.

Niknam V , Meratan AA , Ghaffari S.M. The effect of salt stress on lipid peroxidation and antioxidative enzymes in callus of two Acanthophyllum species. In Vitro Cell Dev. Biol. Plant 2011; 47(2): 297308.

Nizam J , Khan IA , Farook S.A. Ukaz Publication, Hyderabad, pp. 149 149.

Ochatt SJ , Marconi PL , Radice S , Arnozis PA , Caso O.H. In vitro recurrent selection of potato: production and characterization of salt tolerant cell lines and plants. Plant Cell Tissue Organ Cult. 1999; 55: 18.

Olmos E , Hernandez JA , Sevilla F , Hellin E. Induction of several antioxidant enzymes in the selection of a salt-tolerant cell line of Pisum sativum. Plant Physiol. 1994; 144: 594598.

Pandey R , Ganapathy P.S. Isolation of NaCl tolerant callus line of Cicer arietinum L Cv BG-203. Plant Cell Rep. 1984; 3: 4547.

Park EJ , Jeknic Z , Pino MT , Murata N , Chen T.H. Glycinebetaine accumulation in chloroplasts is more effective than that in cytosol in protecting transgenic tomato plants against abiotic stress. Plant Cell Environ. 2007; 30: 9941005.

Parsad VS , Sharmila KP , Kumar PA , Saradhi P.P. Transformation of Brassica juncea (L.) Czern with a bacterial codA gene enhances its tolerance to salt stress. Mol. Breed. 2000; 6: 489499.

Patade VY , Bhargava S , Suprasanna P. Effects of NaCl and iso-osmotic PEG stress on growth, osmolytes accumulation and antioxidant defense in cultured sugarcane cells. Plant Cell Tissue Organ Cult. 2012; 108(2): 279286.

Patade VY , Bhargava S , Suprasanna P. Salt and drought tolerance of sugarcane under iso-osmotic salt and water stress: growth osmolyte accumulation and antioxidant defense. J. Plant Interact. 2011; 6(4): 275282.

Patil P , Rao S. Selection and characterization of NaCl tolerant callus cultures of Vigna radiate (L.) Wilczek. In: Plant Tissue Culture and Biotechnology Emerging Trends (ed. P.B.K. Kishor). Universities Press, Hyderabad, India, 1999.

Patnaik J , Debata B.K. In vitro selection of NaCl tolerant callus lines of Cymbopogon martinii (Roxb.) Wats. Plant Sci. 1997a; 124: 203210.

Patnaik J , Debata B.K. Regeneration of plantlets from NaCl tolerant callus lines of Cymbopogon martinii (Roxb.) Wats. Plant Sci. 1997b; 128: 6774.

Perez-Tornero O , Talln CI , Porras I , Navarro J.M. Physiological and growth changes in micropropagated Citrus macrophylla explants due to salinity. J Plant Physiol. 2009; 166(17): 19231933.

388 Purohit M , Srivastava S , Srivastava P.S. Stress tolerant plants through tissue culture. In: Plant Tissue Culture and Molecular Biology: Application and Prospects (ed. P.S. Srivastava). Narosa Publishing House, New Delhi, 1998, pp.554578.

Quan R , Shang M , Zhang H , Zhao Y , Zhang J. Engineering of enhanced glycine betaine synthesis improves draught tolerance in maize. Plant Biotech. J. 2004; 2: 477486.

Queiros F , Fidalgo F , Santos I , Salema R. In vitro selection of salt tolerant cell lines in Solanum tuberosum L. Biol. Plant. 2007; 51: 728734.

Ramakrishna A , Ravishankar G.A. Influence of abiotic stress signals on secondary metabolites in plants. Plant Sig. Behav. 2011; 6: 17201731.

Ramakrishna A , Ravishankar G.A. Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Climate Change and Plant Abiotic Stress Tolerance (eds. N. Tuteja, and S.S. Gill). Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2013, pp. 705726.

Rao S Krupanidhi . Regeneration of plantlets from sodium chloride (tolerant) cell lines in pigeon pea (Cajanus cajan (L.) Millsp.) 1996. In: Role of Biotechnology in Pulse Crops. Eds. Rao S, Jabeen FTZ. In vitro selection and characterization of polyethylene glycol (PEG) tolerant callus lines and regeneration of plantlets from the selected callus lines in sugarcane (Saccharum officinarum L.). Physiol. Mol. Biol. Plants 2013; 19: 261268.

Reddy PJ , Vaidyanath K. In vitro characterization of salt stress effects and the selection of salt-tolerant plants in rice (Oryza sativa L.). Theor. Appl. Genet. 1986; 71: 757760.

Saijo Y , Hata S , Kyozuka J , Shimamoto K , Izui K. Overexpression of a single Ca2+ dependent protein kinase confers both cold and salt/drought tolerance on rice plants. Plant J. 2000; 23: 319327.

Sairam RK , Rao KV , Srivastava G.C. Differential response of wheat genotypes to longterm salinity stress in relation to oxidative stress, antioxidant activity and osmolytes concentration. Plant Science 2002; 163: 10371046.

Sajid ZA , Faheem Aftab F. Plant regeneration from in vitro-selected salt tolerant callus cultures of Solanum tuberosum L. Pak. J. Bot. 2014; 46(4): 15071514.

Sakhanokho HF , Kelley R.Y. Influence of salicylic acid on in vitro propagation and salt tolerance in Hibiscus acetosella and Hibiscus moscheutos (cv Luna Red). Afr. J. Biotechnol. 2009; 8(8): 14741481.

Sassi A.S. , Aydi S. , Gonzalez E.M. , Abdelly C. Osmotic stress affects water relations, growth, and nitrogen fixation in Phaseolus vulgaris plants. Acta Physiol Plant 2008, 30, 441449.

Sawahel WA , Hassan A.H. Generation of transgenic wheat plants producing high levels of the osmoprotectant proline. Biotechnol. Lett. 2002; 24: 721725.

Sayari AH , Bouzid RG , Bidani A , Jaoua L , Savoure A , Jaoua S. Over expression of 1-pyrroline-5-carboxylate synthetase increases proline production and confers salt tolerance in transgenic potato plants. Plant Sci. 2005; 169: 746752.

Sen A , Alikamanoglu S. Effect of salt stress on Growth parameters and Antioxidant enzymes of different wheat (Triticum aestivum L.) varieties on in vitro tissue culture. Fresenius Environ. Bull. 2011; 20(2a): 489495.

Shah AH , Shah SH , Ahmad H , Swati Z.A. Adaptation to polyethylene stress maintains totipotency of cell lines of Oryza sativa L. CV Swat-1 for a longer period. Pak. J. Bot. 2012; 44(1): 313316.

Shalata A , Tal M. The effect of salt stress on lipid peroxidation and antioxidants in the of the cultivated tomato and its wild salt tolerant relative Lycopersicon pennellii. Physiol. Plant. 1998; 104: 169174.

Shankhdhar D , Shankhdhar SC , Mani SC , Pant R.C. In vitro selection for salt tolerance in rice. Biol. Plantarum 2000; 43(3): 477480.

Shanthi P , Jebaraj S , Geetha S. In vitro screening for salt tolerance in Rice (Oryza sativa). Electron. J. Plant Breed. 2010; 1(4): 12081212.

Shen YG , Du BX , Zhang WK , Zhang JS , Chen S.Y. AhCMO, regulated by stresses in triplex hortensis, can improve drought tolerance in transgenic tobacco. Theor. Appl. Genet. 2002; 105: 815821.

Shao HB , Chu LY , Jaleel CA , Manivannan P , Panneerselvam R , Shao M.A. (2009). Understanding water deficit stress-induced changes in the basic metabolism of higher plants-biotechnologically and sustainably improving agriculture and the ecoenvironment in arid regions of the globe. Crit. Rev. Biotechnol. 29: 131-151

Shirasawa K , Takabe T , Takabe T , Kishitani S. Accumulation of glycine betaine in rice plants that overexpress choline monooxygenase from spinach and evaluation of their tolerance to abiotic stress. Ann. Bot. 2006; 98: 565571.

Singh M , Jaiswal U , Jaiswal V.S. In vitro selection of NaCl-tolerant callus line and regeneration of plantlets in a bamboo (Dendrocalamus strictus Nees.) In Vitro Cell Dev. Biol. Plant 2003; 39: 229233.

Solomon A , Beer S , Waisel Y , Jones GP , Poleg L.G. Effect of NaCl on the carboxylating activity of Rubisco from Tamarix jordanis in the presence and absence of proline related compatible solutes. Physiol. Plant 1994; 90: 189204.

Sreenivasulu N , Ramanjulu S , Rmachandra-Kini K , Prakash HS , Shekar-Shetty H , Savithri HS , Sudhakar C. Total peroxidase activity and peroxidase isoforms as modified by salt stress in two cultivars of fox-tail millet with differential salt tolerance. Plant Sci. 1999; 141: 19.

Su J , Hirji R , Zhang L , He C , Selvaraj G , Wu R. Evaluation of the stress-inducible production of choline oxidase in transgenic rice as a strategy for producing the stress protectant glycine betaine. J. Exp. Bot. 2006; 57(5): 11291135.

Tal M. In vitro selection for salt tolerance in crop plants: theoretical and practical considerations. In Vitro Cell Dev. Biol. Plant 1994; 30: 175180.

B N Tripathi , Gaur J. P. Relationship between copper- and zinc-induced oxidative stress and praline accumulation in Scenedesmus sp. Planta 2004; 219: 397404.

Turkan I , Demiral T. Recent developments in understanding salinity tolerance. Environ. Exp. Bot. 2009; 67: 29.

Tuteja N , Gill SS , Tuteja R. (2011). Plant response to abiotic stress: Shedding light on salt, drought, cold and heavy metal stress. Omics and Plant Abiotic Stress Tolerance 1: 39-64.

Vajrabhaya M , Thanapaisal T , Vajrabhaya T. Development of salt tolerant lines of KDML and LPT rice cultivars through tissue culture. Plant Cell Rep. 1989; 8: 411414.

Van Resenburg L , Kruger GHJ , Kruger H. Proline accumulation as drought tolerance selection criterion: its relationship to membrane integrity and chloroplast ultrastructure in Nicotiana tabacum L. Plant Physiol. 1993; 141: 188194.

Venkataiah P , Christopher T , Subhash K. Selection and characterization of sodium chloride and mannitol tolerant callus lines of red pepper (Capsicum annuum L.). Plant Physiol. 2004; 9(2): 158163.

389 Vinocur B , Altman A. Recent advances in engineering plant tolerance to abiotic stress: achievements and limitations. Curr. Opin. Biotechnol. 2005; 16: 123132.

Wang B , Luttge U , Ratajczak R. Specific regulation of SOD isoforms by NaCl and osmotic stress in leaves of the C3 halophyte Suaeda salsa L. Plant Physiol. 2004; 161: 285293.

Wang W , Vinocur B , Altman A. Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance. Planta 2003; 218: 114.

Watad AEA , Reinhold L , Lerner H.R. Comparison between a stable NaCl selected Nicotiana cell line and the wild type. Plant Physiol. 1983; 73: 624629.

Winicov I. Characterization of rice (Oryza sativa L.) plants regeneration salt-tolerant cell lines. Plant Sci. 1996; 113: 105111.

Woodward AJ , Bennett I.J. The effect of salt stress and abscisic acid on proline production, chlorophyll content and growth of in vitro propagated shoots of Eucalyptus camaldulensis. Plant Cell Tissue Organ Cult. 2005; 82: 189200.

Yamada M , Morishita H , Urano K , Shiozaki N , Yamaguchi-Shinozaki K , Shinozaki K , Yoshiba Y. Effects of free proline accumulation in petunias under drought stress. J. Exp. Bot. 2005; 56: 19751981.

Yamaguchi T , Blumwald E. Developing salt-tolerant crop plants: challenges and opportunities. Trends Plant Sci. 2005; 10: 615620.

Yang P , Wen LL , Zhao C , Zhao B , Yangdong G. Cloning and functional identification of ProDH gene from broccoli. Journal of Guangxi Agricultural and Biological Science 2010; 29: 206214.
Yang WJ , Rich PJ , Axtell JD , Wood KV , Bonham CC , Ejeta G , Mickelbart V , Rhodes D. Genotypic variation for glycine betaine in Sorghum. Crop Sci. 2003; 43: 162169.
Yang X , Wen X , Gong H , Lu Q , Yang Z , Tang Y , Liang Z , Lu C. Genetic engineering of the biosynthesis of glycine betaine enhances thermo tolerance of photosystem II in tobacco plants. Planta 2007; 225: 719733.
Zair I , Chlyah A , Sabounji K , Tittahsen M , Chlyah H. Salt tolerance improvement in some wheat cultivars after application of in vitro selection pressure. Plant Cell Tissue Organ Cult. 2003; 73: 237244.
Zenk M.H. Haploids in physiological and biochemical research. In: Haploids in Higher Plants (ed. K.J. Kasha), Canada University Guelph Press, Ontario, Canada, 1974.
Zhang F , Yang YL , He WL , Zhao X , Zhang L.X. Effects of salinity on growth and compatible solutes of callus induced from Populus euphratica. In Vitro Cell Dev. Biol. Plant 2004; 40: 491494.
Zhang H , Dong H , Li W , Sun Y , Chen S , Kong X. Increased glycine betaine synthesis and salinity tolerance in AhCMO transgenic cotton lines. Mol. Breed. 2009; 23: 289298.
Zhou SF , Chen XY , Xue XN , Zhang XG , Li Y.X. Physiological and growth responses of tomato progenies harboring the betaine aldehyde dehydrogenase gene to salt stress. J. Integr. Plant. Biol. 2007; 49: 628637.
Zhu B , Su J , Chang M , Verma DPS , Fan YL , Wu R. Over expression of a 1 pyrroline 5-carboxylate synthetase gene and analysis of tolerance to water and salt stress in transgenic rice. Plant Sci. 1998; 139: 4148.
Zhu J.K. Salt and drought stress signal transduction in plants. Annu. Rev. Plant Physiol. Plant Mol. Biol. 2002; 53: 247273.

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Abe M , Kobayashi Y , Yamamoto S. (2005). FD, a bZIP protein mediating signals from the floral pathway integrator FT at the shoot apex. Science. 309(5737): 10521056.
Abrahim D , Francischini AC , Pergo EM , Kelmer-Bracht AM , Ishii-Iwamoto E.L. (2003). Effects of -pinene on the mitochondrial respiration of maize seedlings. Plant Physiol. Biochem. 41: 985991.
Agarwal M , Hao Y , Kapoor A. (2006). A R2R3 type MYB transcription factor is involved in the cold regulation of CBF genes and in acquired freezing tolerance. J. Biol. Chem. 281(49): 3763637645.
Agarwal PK , Jha B. (2010). Transcription factors in plants and ABA dependent and independent abiotic stress signalling. Biol. Plant. 54(2): 201212.
Aghaei K , Komatsu S. (2013) Crop and medicinal plants proteomics in response to salt stress. Front. Plant Sci. 4: 8.
Ahmad P , Prasad M.N.V. (2004). Abiotic stress responses in plants. J. Plant Physiol. 168: 807815.
398 Aliabadi FH , Lebaschi MH , Hamidi A. (2008). Effects of arbuscular mycorrhizal fungi, phosphorus and water stress on quantity and quality characteristics of coriander. Appl. Sci. 2(2): 5559.
Aliabadi FH , Valadabadi SAR , Daneshian J , Khalvati M.A. (2009). Evaluation changing of essential oil of balm (Melissa officinalis L.) under water deficit stress conditions. J. Med. Plant. Res. 3(5): 329333.
Alscher RG , Erturk N , Heath L.S. (2002). Role of superoxide dismutase (SODs) in controlling oxidative stress in plants. Exp. Bot. 53: 133141.
Ansari SR , Frooqi AHA , Sharma S. (1998). Interspecific variation in sodium and potassium ion accumulation and essential oil metabolism in three Cymbopogon species raised under sodium chloride stress. J. Essen. Oil Res. 10: 413418.
Arbona V Manzi M , de Ollas C , Gomez-Cadenas A. (2013). Metabolomics as a tool to investigate abiotic stress tolerance in plants. Int. J. Mol. Sci. 14: 48854911.
Arshi A , Abdin MZ , Iqbal M. (2002). Growth and metabolism of senna as affected by salt stress. Biol. Plant. 45: 295298.
Arshi A , Abdin MZ , Iqbal M. (2004). Changes in biochemical status and growth performance of Senna (Cassia angustifolia Vahl.) grown under salt stress. Phytomorphology 54: 109124.
Asbahani AE , Miladi K , Badri W , Sala M , Addi EHA , Casabianca H , A.E., Mousadik , Hartmann D , Jilale A , Renaud FNR , Elaissari A. (2015). Essential oils from extraction to encapsulation. Int. J. Pharm. 483(12): 220243.
Ashraf M , Orooj A. (2006). Salt stress effects on growth, ion accumulation and seed oil concentration in an arid zone traditional medicinal plant ajwain (Trachyspermum ammi L. Sprague). J. Arid. Environ. 64(2): 209220.
Assche FV , Clijsters H. (1990). Effects of metals on enzyme activity in plants. Plant Cell Environ. 13(3): 195206.
Atkinson NJ , Lilley CJ , Peter E. (2013). Identification of genes involved in the response of arabidopsis to simultaneous biotic and abiotic stresses. Plant Physiol. 162(4): 20282041.
Aziz EE , Al-Amier H , Craker L.E. (2008). Inuence of salt stress on growth and essential oil production in peppermint, pennyroyal and apple mint. J. Herbs Spices Med. Plants 14: 7787.
Bartel D. (2004). MicroRNAs: genomics, biogenesis, mechanism, and function. Cell 116: 281297.
Bedi S Tanuja. , Vyas SP . (2008). A Handbook of Aromatic and Essential Oil Plants: Cultivation, Chemistry, Processing and Uses, AGROBIOS Publishers, Jodhpur, India.
Belaqziz R , Romane A , Abbad A. (2009). Salt stress effects on germination, growth and essential oil content of an endemic thyme species in Morocco Thymus maroccanus Ball. J. Appl. Sci. Res. 5: 858863.
Bell E , Mullet J.E. (1991). Lipoxygenase gene expression is modulated in plants by water deficit, wounding and methyl jasmonate. Mol. Gen. Genet. 230: 456462.
Bettaieb I , Zakhama N , Wannes WA , Kchouk ME , Marzouk B. (2008). Water deficit effects on Salvia officinalis fatty acids and essential oils composition. Sci. Hortic. 120: 271275.
Bhatt RM , Rao S.N.K. (2005). Influence of pod load response of okra to water stress. Ind. J. Plant Physiol. 10: 5459.
Bhattacharjee S.K. (2005). A Handbook of Aromatic Plants, Pointer Publishers Vyas-Building, Jaipur, India.
Bogeat-Triboulot MB , Brosche M , Renaut J. (2007). Gradual soil water depletion results in reversible changes of gene expression, protein profiles, ecophysiology, and growth performance in Populus euphratica, a poplar growing in arid regions. Plant Physiol. 143(2): 876892.
Boyer J.S. (1982). Plant productivity and environment. Science 218: 443448.
Broeckling CD , Huhman DV , Farag M.A. (2005). Metabolic profiling of Medicago truncatula cell cultures reveals the effects of biotic and abiotic elicitors on metabolism. J. Exp. Bot. 56(410): 323336.
Camejo D , Rodriguez P , Morales MA , Dell Amico JM , Torrecillas A , Alarcon J.J. (2005). High temperature effects on photosynthetic activity of two tomato cultivars with different heat susceptibility. J. Plant Physiol. 162: 281289 .

Cao HX , Sun CX , Shao HB , Lei X.T. (2011). Effects of low temperature and drought on the physiological and growth changes in oil palm seedlings. Afr. J. Biotechnol. 10: 26302637.

Castellana N , Bafna V. (2010). Proteogenomics to discover the full coding content of genomes: a computational perspective. J. Proteomics. 73: 21242135.

Charles DJ , Joly RJ , Simon J.E. (1990). Effect of osmotic stress on the essential oil content and comparison of peppermint. Phytochemistry 2: 28372840.

Chartzoulakis K , Loupassaki M , Bertaki M , Androulakis I. (2002). Effects of NaCl salinity on growth, ion content and CO2 assimilation rate of six olive cultivars. Sci. Hortic. 96: 235247.

Chatterjee S , Srivastava S , Khalid A. (2010). Comprehensive metabolic fingerprinting of Withania somnifera leaf and root extracts. Phytochemistry 71(10): 10851094.

Chaves MM , Pereira JS , Maroco ML , Rodriques CPP , Ricardo ML , Osorio I , Carvatho TF , Pinheiro C. (2002). How plants cope with water stress in the field photosynthesis and growth. Ann. Bot. 89: 907916.

Chen F , Li Q , Sun L , He Z. (2006). The rice 14-3-3 gene family and its involvement in responses to biotic and abiotic stress. DNA Res. 13(2): 5363.

Christianson JA , Dennis ES , Llewellyn DJ , Wilson I.W. (2010). ATAF NAC transcription factors: regulators of plant stress signaling. Plant Signal. Behav. 5(4): 428432.

Chung IM , Kim JJ , Lim JD , Yu CY , Kim SH , Hahn S.J. (2006). Comparison of resveratrol SOD activity, phenolic compounds and free amino acids in Rehmannia glutinosa under temperature and water stress. Environ. Exp. Bot. 56: 4453.

Croteau R. (2000). Kutchan T, Lewis N. (2000) Natural products (secondary metabolites). In: Biochemistry and Molecular Biology of Plants, B Buchanan, W Gruissem, R Joneas, (eds.). American Society of Plant Biologists, Rockville, MD, pp. 12501268.

Delfine S , Loreto F , Pinell P , Tognetti R , Alvino A. (2005). Isoprenoids content and photosynthetic limitations in rosemary and spearmint plants under water stress. Agric. Ecosyst. Environ. 106: 243252.

Djilani A , Dicko A. (2012). The Therapeutic Benefits of Essential Oils, Nutrition, Well Being and Health, Jaouad Bouayed (ed.). ISBN: 978-953-51-0125.

Djoukeng JD , Arbona V , Argamasilla R , Gomez C. (2008). Flavonoid profiling in leaves of citrus genotypes under different environmental situations. J. Agric. Food Chem. 56(23): 1108711097.

Dorman HJD , Figueiredo AC , Barraso G , Deans S.G. (2000). In vitro evaluation of antioxidant activity of essential oils and their components. Flavour. Fragr. J. 15: 1216.

Dow AI , Cline TA , Horning E.V. (1981). Salt tolerance studies on irrigated mint. Bulletin of Agriculture Research Center, Washington State University, Pullman. 906: 11.

399 Dubos C , Stracke R , Grotewold E , Weisshaar B , Martin C , Lepiniec L. (2010). MYB transcription factors in Arabidopsis. Trends. Plant Sci. 15(10): 573581.

Dudareva N , Pichersky E , Gershenzon J. (2004). Biochemistry of plant volatiles. Plant Physiol. 135: 18931902.

Farooq M , Basra SMA , Wahid A , Cheema ZA , Cheema MA , Khaliq A. (2008). Physiological role of exogenously applied glycinebetaine in improving drought tolerance of fine grain aromatic rice (Oryza sativa L.). J. Agron. Crop Sci. 194: 325333.

Fatima S , Farooqi AHA , Sangwan R.S. (2006). Water stress mediated modulation in essential oil, proline and polypeptide profile in palmarosa and citronella java. In: Physiology and Molecular Biology of Plants. Lucknow, India: Central Institue of Medicinal and Aromatic Plants, CIMAP.

Flowers T.J. (2004). Improving crop salt tolerance. J. Exp. Bot. 55(396): 307319.

Foy C.D. (1988). Plant adaptation to acid, aluminum-toxic soils. Commun. Soil Sci. Plant Anal. 19: 959987.

Fu D , Huang B , Xiao Y , Muthukrishnan S , Liang G.H. (2007). Overexpression of barley hva1 gene in creeping bentgrass for improving drought tolerance. Plant Cell Rep. 26(4): 467477.

Fujimoto SY , Ohta M , Usui A , Shinshi H , Ohme-Takagi M. (2000). Arabidopsis ethylene-responsive element binding factors act as transcriptional activators or repressors of GCC box-mediated gene expression. Plant Cell 12(3): 393404.

Fukushima A , Kusano M , Redestig H , Arita M , Saito K. (2011). Metabolomic correlation-network modules in Arabidopsis based on a graph-clustering approach. BMC Syst. Biol. 5(1): 112.

Geissman TA , Crout D.H.G. (1969). Organic Chemistry of Secondary Plant Metabolism. Freeman. San Francisco., T. Robinson . (1969). The Organic Constituents of Higher Plants. Cordus, Amherst, Mass ed., M. Luckner . (1983). Secondary Metabolism in Plants and Animals. Academic Press. New York, 1972.

Hendawy SF , Khalid K.A. (2005). Response of sage (Salvia officinalis L.) plants to zinc application under different salinity levels. J. Appl. Sci. Res. 1: 147155.

Hikosaka K , Muradami A , Hirose T. (1999). Balancing carboxylation and regeneration of ribulose- 1, 5-bisphosphate in leaf photosynthesis: temperature acclimation of an evergreen tree, Quereus myrsinaefolia. Plant Cell Environ. 22: 841849.

Hsiao T.C. (1973). Plant responses to water stress. Annu. Rev. Plant Physiol. 24: 519570.

Jaleel CA , Gopi R , Panneerselvam R. (2008). Growth and photosynthetic pigments responses of two varieties of Catharanthus roseus to triadimefon treatment. C. R. Biol. 331: 272277.

Jaleel CA , Gopi R , Panneerselvam R. (2009). Alterations in non-enzymatic antioxidant components of Catharanthus roseus exposed to paclobutrazol, gibberellic acid and Pseudomonas fluorescens. Plant Omics 2(1): 3040.

Jaleel CA , Gopi R , Sankar B , Gomathinayagam M , Panneerselvam M. (2008). Differential responses in water use efficiency in two varieties of Catharanthus roseus under drought stress. C. R. Biol. 331: 4247.

Jaleel CA , Manivannan P , Kishorekumar AB , Sankar R , Gopi R , Somasundaram P.R. (2007). Alterations in osmoregulation, antioxidant enzymes and indole alkaloid levels in Catharanthus roseus exposed to water deficit. Colloids. Surf. B. Biointerfaces. 59: 150157.

Jaleel CA , Manivannan P , Sankar B , Kishorekumar A , Gopi R , Somasundaram R , Panneerselvam R. (2007). Water deficit stress mitigation by calcium chloride in Catharanthus roseus; effects on oxidative stress, proline metabolism and indole alkaloid accumulation. Colloids. Surf. B. Biointerfaces. 60: 110116.

Jason JG , Thomas GR , Mason-Pharr D. (2004). Heat and drought influence photosynthesis, water relations and soluble carbohydrates of two ecotypes of redbud (Cercis Canadensis). J. Am. Soc. Hort. Sci. 129(4): 497502.

Jaspers P , Kangasjarvi J. (2010). Reactive oxygen species in abiotic stress signaling. Physiol. Plantarum. 138(4): 405413.

Kashyap PL , Sanghera GS , Wani SH , Shai W , Kumar S. (2011). Genes of microorganisms paving way to tailor next generation fungal disease resistant crop plants. Not. Sci. Biol. 3: 147157.

Kaur SK , Nayyar G.H. (2008). Exogenous application of abscisic acid improves cold tolerance in chickpea (Cicer arietinum L.). J. Agron. Crop Sci. 194: 449456.

Khalid K.A. (2006). Influence of water stress on growth, essential oil, and chemical composition of herbs (Ocimum sp.). Int. Agrophys. 20(4): 289296.

Kirakosyan A , Kaufman P , Warber S , Zick S , Aaronson K , Bolling S , Chul Chang S. (2004). Applied environmental stresses to enhance the levels of polyphenolics in leaves of hawthorn plants. Physiol. Plant. 121: 182186.

Koussevitzky S , Suzuki N , Huntington S , Armijo L , Sha W , Cortes D. (2008). Ascorbate peroxidase 1 plays a key role in the response of Arabidopsis thaliana to stress combination. J. Biol. Chem. 283: 3419734203.

Kulcheski FR , de Oliveira Lfv , Molina LG , Almerao MP , Rodrigues FA , Marcolino J. (2011). Identification of novel soybean microRNAs involved in abiotic and biotic stresses. BMC Genom. 12 (307): 117.

Kumar A , Abrol Y.P. (1994). Effect of gypsum on five tropical grasses grown in normal and extensive sodic soil. Exp. Agr. 19: 169177.

Kumar AA , Gill K.S. (1995). Performance of aromatic grasses under saline and sodic stress condition. Salt tolerance of aromatic grasses. Indian Perfum. 39: 3944.

Lepiniec L , Debeaujon I , Routaboul J.M. (2006). Genetics and biochemistry of seed flavonoids. Annu. Rev. Plant Biol. 57: 405430.

Ludlow MM , Muchow R.C. (1990). A critical evaluation of the traits for improving crop yield in water limited environments. Adv. Agron. 43: 107153.

Maheshwar P , Kovalchuk I. (2014). Genetic engineering of oilseed crops. Biocatal. Agric. Biotechnol. 3: 3137.

Mahmoud SS , Croteau R.B. (2002). Strategies for transgenic manipulation of monoterpene biosynthesis in plants. Trends Plant Sci. 7: 366373.

Mandaokar A , Browse J. (2009). MYB108 acts together with MYB24 to regulate jasmonate-mediated stamen maturation in Arabidopsis. Plant Physiol. 2(149): 851862.

Mann J. (1978). Secondary metabolism. Bell EA , Charlwood BV , Eds., Encylopedia of Plant Physiology. Springer-Verlag, New York, 1980. vol. 8.J. Meinwald., G.D. Prestwich., K. Nakanishi., I. Rubo., Science 199: 1167.

Melzer E , OLeary M. (1987). Anapleurotic CO2 fixation by phosphoenolpyruvate carboxylase in C3 plants. Plant Physiol. 84: 5860.

400 Michael BJ , Kimiharu I , Osamu I. (2009). Evolution and mechanisms of plant tolerance to flooding stress. Ann. Bot. 103: 137142.

Min SY , Tawaha ARM , Lee K.D. (2005). Effects of ammonium concentration on the yield, mineral content and active terpene components of Chrysanthemum coronarium L. in a hydroponic system. Res. J. Agric. Biol. Sci. 1: 170175.

Mittler R. (2002). Oxidative stress, antioxidants and stress tolerance. Trends Plant Sci. 7(9): 405410.

Mizoi J , Shinozaki K , Yamaguchi-Shinozaki K . (2012). AP2/ERF family transcription factors in plant abiotic stress responses. Biochim. Biophys. Acta 1819(2): 8696.

Mohamed MAH , Harris PJC , Henderson J , Senatore F. (2002). Effect of drought stress on the yield and composition of volatile oils of drought-tolerant and non-drought-tolerant clones of Tagetes minuta. Planta Med. 68(5): 472474.

Moussa H.R. (2006). Influence of exogenous application of silicon on physiological response of salt-stressed maize (Zea mays L.). IJAB. 3(8): 293297.

Munns R , Tester M. (2008). Mechanisms of salinity tolerance. Annu. Rev. Plant Biol. 59: 651681.

Muzik RM , Pregitzer KS , Hanover J.W. (1989). Changes in terpene production following nitrogen fertilization of grand fir Abies grandis (Dougl.) Lindl. seedlings. Oecologia 80: 485489.

Nakagami H , Soukupova H , Schikora A , Zarsky Z , Hirt H. (2006). A mitogen-activated protein kinase kinase kinase mediates reactive oxygen species homeostasis in Arabidopsis. J. Biol. Chem. 281(50): 3869738704.

Nakano T , Suzuki K , Fujimura T , Shinshi H. (2006). Genome wide analysis of the ERF gene family in Arabidopsis and rice. Plant Physiol. 140(2): 411432.

Nakashima K , Takasaki H , Mizoi J , Shinozaki K , Yamaguchi-Shinozaki K . (2011). NAC transcription factors in plant biotic and abiotic stress responses. Biochim. Biophys. Acta 1819(2): 97103.

Neffati M , Marzouk B. (2008). Changes in essential oil and fatty acid composition in coriander (Coriandrum sativum L) leaves under saline conditions. Ind. Crops Prod. 28: 137142.

Neill S , Desikan R , Clarke S , Hurs RD , Hancock J.T. (2002). Hydrogen peroxide and nitric oxide as signaling molecules in plants. J. Exp. Bot. 53: 12371247.

Nostro A , Germano MP , Dangelo V , Marino A , Cannatelli M.A. (2000). Extraction methods and bioautography for evaluation of medicinal plant antimicrobial activity. Lett. Appl. Microbiol. 30: 379384.

Onate-Sanchez L , Singh K.B. (2002). Identification of Arabidopsis ethylene-responsive element binding factors with distinct induction kinetics after pathogen infection. Plant Physi ol. 128(4): 13131322.

Ozkan A , Kulak M. (2013). Effects of water stress on growth, oil yield, fatty acid composition and mineral content of Sesamum indicum. J. Anim. Plant Sci. 23(6): 16861690.

Patade VY , Suprasanna P. (2010). Short-term salt and PEG stresses regulate expression of MicroRNA, miR159 in sugarcane leaves. J. Crop Sci. Biotechnol. 13(3): 177182.

Peleman JD , van der Voort J.R. (2003). Breeding by design. Trends Plant Sci. 8(7): 330334.

Perez-Alfocea F , Ghanem ME , Gomez-Cadenas A , Dodd I.C. (2011). Omics of root-to-shoot signaling under salt stress and water deficit. OMICS. 15(12): 893901.

Pichersky E , Gershenzon J. (2002). The formation and function of plant volatiles: perfumes for pollinator attraction and defense. Curr. Opin. Plant Biol. 5: 237243.

Pichersky E , Noel JP , Dudareva N. (2006). Biosynthesis of plant volatiles: natures diversity and ingenuity. Science 311: 808811.

Pirzad A , Alyari H , Shakiba MR , Zehtab-Salmasi S , Mohammadi A. (2006). Essential oil content and composition of German chamomile (Matricaria chamomilla L.) at different irrigation regimes. J. Agron. 5(3): 451455.

Pitzschke A , Schikora A , Hirt H. (2009). MAPK cascade signaling networks in plant defense. Curr. Opin. Plant Biol. 12(4): 421426.

Qiao-Ying Z , Yang CY , Ma QB , Li XP , Dong WW , Nian H. (2012). Identification of wild soybean miRNAs and their target genes responsive to aluminum stress. BMC Plant Biol. 12: 182.

Rahman H , Harwood JL , Weselake R. (2013). Increasing seed oil content in Brassica species through breeding and biotechnology. Lipid Technol. 25: 182185.

Rahmani N , Farahani H , Valadabadi S.A.R. (2008). Effects of nitrogen on oil yield and its component of Calendula (Calendula officinalis L.) in drought stress conditions. Abstracts Book of The World Congress on Medicinal and Aromatic Plants, South Africa, p. 36.

Ramakrishna A and Ravishankar G.A. (2011). Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal. Behav. 6: 17201731.

Ramakrishna A , Ravishankar G.A. (2013). Role of plant metabolites in abiotic stress tolerance under changing climatic conditions with special reference to secondary compounds. In: Climate Change and Abiotic Stress Tolerance, N. Tuteja and S.S. Gill (eds.). Wiley-VCH, Weinheim. ISBN 978-3-527-33491-9.

Rao BRR , Kaul PN , Syamasundar KV , Ramesh S. (2005). Chemical profiles of primary and secondary essential oils of palmarosa (Cymbopogon martini (Roxb.) Wats var. motia Burk.). Ind. Crops Prod. 21: 121127.

Reddy PCO , Sairanganayakulu G , Thippeswamy M , Reddy PS , Reddy MK , Sudhakar C.H. (2008). Antioxidant enzyme activities and gene expression patterns in leaves of Kentucky blue grass in response to drought and post-drought recovery. Plant Sci. 175: 372384.

Reinhart BJ , Weinstein EG , Rhoades MW , Bartel B , Bartel D.P. (2002). MicroRNAs in plants. Genes Dev. 16: 16161626.

Said-Al Ahl Hah , Omer E.A. (2011). Medicinal and aromatic plants production under salt stress. Herba Pol. 57: 7287.

Sakuma Y , Maruyama K , Qin F , Osakabe Y , Shinozaki K , Yamaguchi-Shinozaki K. (2006). Dual function of an Arabidopsis transcription factor DREB2A in water- stress-responsive and heat-stressresponsive gene expression. Proc. Natl. Acad. Sci. U.S.A. 103: 1882218827.
Sanghera GS , Kashyap PL , Singh G , da Silva J.A.T. (2011). Transgenics: fast track to plant stress amelioration. Transgenic Plant. J. 5: 126.
Sangwan NS , Farooqi AH , Sangwan R.S. (1994). Effects of drought stress on growth and essential oil metabolism in lemongrasses. New Phytol. 128: 173179.
Seger C , Sturm S. (2007). Analytical aspects of plant metabolite profiling platforms: current standings and future aims. J. Proteome Res. 6(2): 480497.
401 Seo PJ , Park C.M. (2010). MYB 96-mediated abscisic acid signals induce pathogen resistance response by promoting salicylic acid biosynthesis in Arabidopsis. New Phytol. 186(2): 471483.
Shao HB, Chu LY, Jaleel CA, Manivannan P, Panneerselvam R, Shao MA. (2009). Understanding water deficit stress-induced changes in the basic metabolism of higher plants-biotechnologically and sustainably improving agriculture and the ecoenvironment in arid regions of the globe. Crit. Rev. Biotechnol. 29: 131151.
Shukla LI , Chinnusamy V , Sunkar R. (2008). The role of microRNAs and other endogenous small RNAs in plant stress responses. Biochim. Biophys Acta. 1779: 743748.
Shulaev V. (2006). Metabolomics technology and bioinformatics. Brief Bioinform. 7(2): 128139.
Simon JE , Bubenheim DR , Joly RJ , Charles D.J. (1992). Water stress induced alterations in essential oil content and composition of sweet basil. JEOR. 4: 7175.
Singh M , Ramsh S. (2000). Effect of irrigation and nitrogen on herbage, oil yield and water use efficiency in rosemary grown under semi-arid and tropical conditions. J. Med. Aromat Plant Sci. 22: 659662.
Somesh M , Rupali S , Swati S , Jose M , Manish M. (2015). In vitro comparative study on antimicrobial activity of five extract of few citrus fruit: peel & pulp vs Gentamicin. AJBAS 9(1): 165173.
Stutte G.W. (2006). Process and product: recirculation hydroponics and bioactive compounds in a controlled environment. HortScience 41: 526530.
Sun G , Stewart C , Jr N , Xiao P , Zhang B. (2012). MicroRNA expression analysis in the cellulosic biofuel crop Switchgrass (Panicum virgatum) under abiotic stress. PLoS ONE 7: e32017.
Sunkar R , Zhu J.K. (2004). Novel and stress-regulated microRNAs and other small RNA from Arabidopsis. Plant Cell 16: 20012019.
Tabatabaie SJ , Nazari, J. (2007). Inuence of nutrient concentration and NaCl salinity on growth, photosynthesis and essential oil content of peppermint and lemon verbena. Turk J. Agric. For. 31: 245253.
Tuteja N, Gill SS, Tuteja R. (2011). Plant response to abiotic stress: Shedding light on salt, drought, cold and heavy metal stress. Omics and Plant Abiotic Stress Tolerance 1: 3964.
Wang W , Vinocur B , Altman A. (2003). Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance. Planta 218: 114.
Wang Y , Ying J , Kuzma M , Chalifoux M , Sample A , McArthur C , Uchacz T , Sarvas C , Wan J , Dennis DT , McCourt P , Huang Y. (2005). Molecular tailoring of farnesylation for plant drought tolerance and yield protection. Plant J. 43: 413424.
Widodo., Patterson JH , Newbigin E , Tester M , Bacic A , Roessner U. (2009). Metabolic responses to salt stress of barley (Hordeum vulgare L.) cultivars, Sahara and Clipper, which differ in salinity tolerance. J. Expt. Bot. 60(14): 40894103.
Wu L , Chen X , Ren H. (2007). ERF protein JERF1 that transcriptionally modulates the expression of abscisic acid biosynthesis-related gene enhances the tolerance under salinity and cold in tobacco. Planta 226(4): 815825.
Yan QC , Kuo MS , Li S. (2008). AGPAT6 is a novel microsomal glycerol-3-phosphate acyltransferase. J. Biol. Chem. 283(15): 1004810057.
Yang XY , Jiang W.J. , Yu H.J. (2012). The expression profiling of the lipoxygenase (LOX) family genes during fruit development, abiotic stress and hormonal treatments in cucumber (Cucumis sativus L.). Int. J. Mol. Sci. 13: 24812500.
Yeager N. (2017). The Environmental Impact of Essential Oils. http://www.earthisland.o rg.
Yoshimura K , Miyao K , Gaber A , Takeda T , Kanaboshi H , Miyasaka H , Shigeoka S. (2004). Enhancement of stress tolerance in transgenic tobacco plants overexpressing Chlamydomonas peroxidase in chloroplasts or cytosol. Plant J. 37: 2133.
Zhang L , Zhao G , Jia J , Liu X. (2011). Molecular characterization of 60 isolated wheat MYB genes and analysis of their expression during abiotic stress. J. Expt. Bot. 63(1): 203214.
Zhang X , Long W , Zoul X , Lil F , Nishio T. (2014). Recent progress in drought and salt tolerance studies in Brassica crops. Breed. Sci. 64: 6073.
Zhao BT , Liang RQ , Ge LF , Li W , Xiao HS , Lin HX , Ruan KC , Jin Y.X. (2007). Identification of drought induced microRNAs in rice. Biochem. Biophys. Res. Commun. 354: 585590.
Zhou X , Wang G , Sutoh K , Zhu JK , Zhang W. (2008). Identification of cold-inducible microRNAs in plants by transcriptome analysis. Biochim. Biophys Acta. 1779: 780788.
Zhu J.K. (2003). Regulation of ion homeostasis under salt stress. Curr. Opin. Plant Biol. 6: 441445.
Zhu Z , Liang Z , Han R. (2009). Saikosaponin accumulation and antioxidative protection in drought-stressed Bupleurum chinense DC plants. Environ. Exp. Bot. 66: 326333.

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Afonso-Grunz F. , Molina C. , Hoffmeier K. , Rycak L. , Kudapa H. , Varshney R.K. , Drevon J.J. , Winter P. , and Kahl G. Genome-based analysis of the transcriptome from mature chickpea root nodules. Front. Plant Sci. 2014, 5, 235.
Agarwal G. , Jhanwar S. , Priya P. , Singh V.K. , Saxena M.S. , Parida S.K. , Garg R. , Tyagi A.K. , and Jain M. Comparative analysis of Kabuli chickpea transcriptome with Desi and wild chickpea provides a rich resource for development of functional markers. PLoS One 2012, 7(12), e52443.
Anbazhagan K. , Bhatnagar-Mathur P. , Valdez V. , Dumbala S.R. , Kishor P.B. , and Sharma K.K. DREB1A overexpression in transgenic chickpea alters key traits influencing plant water budget across water regimes. Plant Cell Rep. 2014, 34, 199210.
Ashraf M. and Foolad M.R. Roles of glycine betaine and proline in improving plant abiotic stress tolerance. Environ. Exp. Bot. 2007, 59, 206216.
Awasthi R. , Kaushal N. , Vadez V. , Turner N.C. , Berger J. , Siddique K.H.M. , and Nayyar H. Individual and combined effects of transient drought and heat stress on carbon assimilation and seed filling in chickpea. Funct. Plant Biol. 2014, 41, 11481167.

Basu P. S. , Berger J.D. , Turner N.C. , Chaturvedi S.K. , Ali M. , and Siddique K.H.M. Osmotic adjustment of chickpea (Cicer arietinum) is not associated with changes in carbohydrate composition or leaf gas exchange under drought. Ann. Appl. Biol. 2007, 150, 217225.

Behboudian M.H. , Ma Q. , Turner N.C. , and Palta J.A. Reactions of chickpea to water stress: yield and seed composition. J. Sci. Food Agric. 2001, 81, 12881291.

Bharadwaj C. , Kumar S. , Singhal T. , Kumar T. , Singh P. , Tripathi S. , Pal M. , Hegde V.S. , Jain P.K. , Chauhan S. , Kumar Verma A. , Roorkiwal M. , Gaur P.M. , and Varshney R.K. . Genomic approaches for breeding drought-tolerant chickpea. Conference Paper, NGG-P11. 5th International Conference on Next Generation Genomics and Integrated Breeding for Crop Improvement (ICRISAT), Patancheru, India, February 1820, 2015.

Boyer J.S. Plant productivity and environment. Science 1982, 218, 443448.

Boyer J.S., and Knipling E.B. Isopiestic technique for measuring leaf water potentials with a thermocouple psychrometer. Proc Natl Acad Sci USA 1965, 54, 10441051.

Cerekovic N. , Fatnassi N. , Horres R. , Santino A. , and Poltronieri P. Differences in physiology response and adaptation to osmotic and drought stress in Kabuli-type Amdoun-1 and Beja 1, and Desi-type ICC 4958 and ICC 6098, chickpea varieties. Sci. China Life Sci., in press.

Cerekovic N., Fatnassi N., Santino A., Poltronieri P. Differences in physiological, biochemical, and molecular mechanisms of water stress tolerance in chickpea varieties. Chapter 6. In: Approaches in Enhancing Abiotic Stress Tolerance to Plants (Hasanuzzaman M., Fujita M., Oku H., Islam T.; Eds). Taylor and Francis, CRC in press, 2019. Catalog n. K345347.

Chen T.H. and Murata N. Enhancement of tolerance of abiotic stress by metabolic engineering of betaines and other compatible solutes. Curr. Opin. Plant Biol. 2002, 5, 250257.

Davies S.L. , Turner N.C. , Palta J.A. , Siddique K.H.M. , and Plummer J.A. Remobilisation of carbon and nitrogen supports seed filling in chickpea subjected to water deficits. Aust. J. Agric. Res. 2000, 51, 855866.

De Domenico S. , Bonsegna S. , Horres R. , Pastor V. , Taurino M. , Poltronieri P. , Imtiaz M. , Kahl G. , Flors V. , Winter P. , and Santino A. Transcriptomic analysis of oxylipin biosynthesis genes and chemical profiling reveal an early induction of jasmonates in chickpea roots under drought stress. Plant Physiol. Biochem. 2012, 62, 115122.

Deokar A.A. , Kondawar V. , Jain P.K. , Karuppayil S.M. , and Raju N.L. Comparative analysis of expressed sequence tags (ESTs) between drought-tolerant and susceptible genotypes of chickpea under terminal drought stress. BMC Plant Biol. 2011, 11, 70.

Esfahani M.N. , Sulieman S. , Schulze J. , Yamaguchi-Shinozaki K. , Shinozaki K. , and Tran L.S. Mechanisms of physiological adjustment of N2 fixation in chickpea (Cicer arientum L.) during early stages of water deficit: Single or multi-factor controls? Plant J. 2014a, 79, 964980. doi: 1111/tpj.12599.

Esfahani M.N. , Sulieman S. , Schulze J. , Yamaguchi-Shinozaki K. , Shinozaki K. , and Tran L.S. Approaches for enhancement of N2 fixation efficiency of chickpea (Cicer arietinum L.) under limiting nitrogen conditions. Plant Biotechnol. J. 2014b, 12(3), 387397.

Fang X. , Turner N.C. , Yan G. , Li F. , and Siddique K.H.M. Flower numbers, pod production, pollen viability, and pistil function are reduced and flower and pod abortion increased in chickpea (Cicer arietinum L.) under terminal drought. J. Exp. Bot. 2010, 61, 335345.

Farooq M. , Gogoi N. , Barthakur S. , Baroowa B. , Bharadwaj N. , Alghamdi S.S. , and Siddique K.H.M. Drought stress in grain legumes during reproduction and grain filling. J. Agron. Crop Sci. 2016, 203(2), 81102. doi:10.1111/jac.12169

Farquhar G.D. and Sharkey T.D. Stomatal conductance and photosynthesis. Annu. Rev. Plant Physiol. 1982, 33, 317345.

Foyer H.C. Redox homeostasis and antioxidant signaling: A metabolic interface between stress perception and physiological responses. Plant Cell 2005, 17, 18661875.

Galvez L. , Gonzalez E.M. , and Arrese-Igor C. Evidence for carbon flux shortage and strong carbon/nitrogen interactions in pea nodules at early stages of water stress. J. Exp. Bot. 2005, 56, 25512561.

Garg R. , Batthacharjee A. , and Jain M. Genomic scale transcriptomic insights into molecular aspects of abiotic stress response in chickpea. Plant Mol. Biol. Rep. 2015, 33, 388400.

Garg R. , Patel R.K. , Jhanwar S. , Priya P. , Bhattacharjee A. , Yadav G. , Bhatia S. , Chattopadhyay D. , Tyagi A.K. , and Jain M. Gene discovery and tissue-specific transcriptome analysis in chickpea with Massively Parallel Pyrosequencing and web resource development. Plant Physiol. 2011, 156, 16611678.

Gonzalez E.M. , Gordon A.J. , James C.L. , and Arrese-Igor C. The role of sucrose synthase in the response of soybean nodules to drought. J. Exp. Bot. 1995, 46, 15151523.

Gupta V. , Bhatia S. , Mohanty N.A. , Sethy N. , and Tripathy B.C. Comparative analysis of photosynthetic and biochemical characteristics of Desi and Kabuli gene pools of chickpea (Cicer arietinum L.). Int. J. Gen. Eng. Biotechnol. 2010, 1, 6576.

410 Hamwieh A. , Imtiaz M. , and Malhotra R.S. Multi-environment QTL analyses for drought-related traits in a recombinant inbred population of chickpea (Cicer arietinum L.). Theor. Appl. Genet. 2013, 126, 10251038.

Hasibeder R. , Fuchslueger L. , Richter A. , and Bahn M. Summer drought alters carbon allocation to roots and root respiration in mountain grassland. New Phytol. 2015, 205(3), 11171127.

Hiremath P.J. , Farmer A. , Cannon S.B. , Woodward J. , Kudapa H. , Tuteja R. , Kumar A. , Bhanuprakash A. , Mulaosmanovic B. , Gujaria N. , Krishnamurthy L. , Gaur P.M. , Kavikishor. P.B. , Shah T. , Srinivasan R. , Lohse M. , Xiao Y. , Town C.D. , Cook D.R. , May G.D. , and Varshney R.K. Large-scale transcriptome analysis in chickpea (Cicer arietinum L.), an orphan legume crop of the semi-arid tropics of Asia and Africa. Plant Biotechnol. J. 2011, 9, 922931.

Jain D. and Chattopadhyay D. Analysis of gene expression in response to water deficit of chickpea (Cicer arietinum L.) varieties differing in drought tolerance. BMC Plant Biol. 2010, 10, 24.

Jayashree B. , Buhariwalla H.K. , Shinde S. , and Crouch J.H. A legume genomics resource: the chickpea root expressed sequence tag database. Electron. J. Biotechnol. 2005, 8, 128133.

Kahl G. , Molina C.M. , and Winter P. Functional genomics-transcriptomics for legumes: background, tools and insights. In: Perez de la Vega M. , Torres A.M. , Cubero J.I. , and Kole C. , Eds. Genetics, Genomics and Breeding of Cool Season Grain Legumes, pp. 237284. CRC Press, Boca Raton, FL, 2011.

Karamanos A.J. and Papatheohari A.Y. Assessment of drought resistance of crop genotypes by means of the water potential index. Crop Sci. 1999, 39, 17921797.

Kashiwagi J. , Krishnamurthy L. , Crouch J.H. , and Serraj R. Variability of root characteristics and their contribution to seed yield in chickpea (Cicer arietinum L.) under terminal drought stress. Field Crop Res. 2006, 95, 171181.

Kashiwagi J. , Krishnamurthy L. , Upadhyaya, H.D. , and Gaur, P.M. Rapid screening technique for canopy temperature status and its relevance to drought tolerance improvement in chickpea. J. SAT Agric. Res. 2008, 6, 14.

Kashiwagi J. , Krishnamurthy L. , Upadhyaya H. D. , Krishna H. , Chandra S. , Vadez V. , and Serraj R. Genetic variability of drought-avoidance root traits in the mini-core germplasm collection of chickpea (Cicer arietinum L.). Euphytica 2005, 146, 213222.

Kavikishore P.B. , Hong Z. , Miao G.H. , Hu C.A.A. , and Verma D.P.S. Overexpression of D1-pyrroline-5-carboxylate synthetase increases proline production and confers osmotolerance in transgenic plants. Plant Physiol. 1995, 108, 13871394.

Krishnamurthy L. , Kashiwagi J. , Gaur P.M. , Upadhyaya H.D. , and Vadez V. Sources of tolerance to terminal drought in the chickpea (Cicer arietinum L.) minicore germplasm. Field Crops Res. 2010, 119, 322330.

Krishnamurthy L. , Kashiwagi J. , Upadhyaya H.D. , Gowda C.L.L. , Gaur P.M. , Singh S. , Purushothaman R. , and Varshney R.K. Partitioning coefficient: A trait that contributes to drought tolerance in chickpea. Field Crops Res. 2013, 149, 354365.
Kumar A. , Bernier J. , Verulkar S. , Lafitte H.R. , and Atlin G.N. Breeding for drought tolerance: Direct selection for yield, response to selection and use of drought-tolerant donors in upland and lowland-adapted populations. Field Crops Res. 2008, 107, 221231.
Kumar T. , Bharadwaj C. , Rizvi A.H. , Sarker A. , Tripathi S. , Alam A. , and Chauhan S.K. Chickpea landraces: A valuable and divergent source for drought tolerance. Int. J. Trop. Agric. 2015, 33(3), 16.
Kurdali F. , Al-Chammaa M. , and Mouasess A. Growth and nitrogen fixation in silicon and/or potassium fed chickpeas grown under drought and well watered conditions. J. Stress Physiol. Biochem. 2013, 9, 385406.
Labidi N. , Mahmoudi H. , Dorsaf M. , Slama I. , and Abdelly C. Assessment of intervarietal differenc es in drought tolerance in chickpea using both nodule and plant traits as indicators. J. Plant Breed. Crop Sci. 2009, 1(4), 080086.
Larrainzar E. , Wienkoop S. , Scherling C. , Kempa S. , Ladrera R. , Arres-Igor C. , and Gonzalez E.M. Medicago truncatula root nodule proteome analysis reveals differential plant and bacteroid responses to drought stress. Plant Physiol. 2007, 144, 14951507.
Lemoine R. , La Camera S. , Atanassova R. , Ddaldchamp F. , Allario T. , Pourtau N. , Bonnemain J. L. , Laloi M. , Coutos-Thvenot P. , Maurousset L. , Faucher M. , Girousse C. , Lemonnier P. , Parrilla J. , and Durand M. Source-to-sink transport of sugar and regulation by environmental factors. Front Plant Sci. 2013, 4, 272.
Leport L. , Turner N.C. , Davies S.L. , and Siddique K.H.M. Variation in pod production and abortion among chickpea cultivars under terminal drought. Eur. J. Agron. 2006, 24, 236246.
Leport L. , Turner, N.C. , French R.J. , Barr M.D. , Duda R. , Davies S.L. , Tennant D. , and Siddique K.H.M. Physiological responses of chickpea genotypes to terminal drought in a Mediterranean-type environment. Eur. J. Agron. 1999, 11, 279291.
Leport L. , Turner N.C. , French R.J. , Tennant D. , Thomson B.D. , and Siddique K.H.M. Water relations, gas-exchange, and growth of cool-season grain legumes in a Mediterranean-type environment. Eur. J. Agron. 1998, 9, 295303.
Liu F. , Jensen C.R. , and Andersen M.N. A review of drought adaptation in crop plants: changes in vegetative and reproductive physiology induced by ABA-based chemical signals. Aust. J. Agric. Res. 2005, 56, 12451252.
Maccarrone M. , Veldink G.A. , Agro A.F. , and Vliegenthart J.F. Modulation of soybean lipoxygenase expression and membrane oxidation. by water deficit. FEBS Lett. 1995, 371, 223226.
Mafakheri A. , Siosemardeh A. , Bahramnejad B. , Struik P.C. , and Sohrabi Y. Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. Aust. J. Crop Sci. 2010, 4, 580585.
Mantri N.L. , Ford R. , Coram T.E. , and Pang E.C.K. Transcriptional profiling of chickpea genes differentially regulated in response to high-salinity, cold and drought. BMC Genomics 2007, 8,303.
Mathur P.B. , Vadez V. , Jyotsna Devi M. , Lavanya M. , Vani G. , and Sharma K.K. Genetic engineering of chickpea (Cicer arietinum L.) with the P5CSF129A gene for osmoregulation with implications on drought tolerance. Mol. Breed. 2009, 23, 591606.
Mhadhbi H. , Jebara M. , Zitoun A. , Limam F. , and Aouani M.E. Symbiotic effectiveness and response to mannitol-mediated osmotic stress of various chickpearhizobia associations. World J. Microbiol. Biotechnol. 2008, 24, 10271035.
Mir R.R. , Zaman-Allah M. , Sreenivasulu N. , Trethowan R. , and Varshney R.K. Integrated genomics, physiology and breeding approaches for improving drought tolerance in crops. Theor. Appl. Genet. 2012, 125, 625645.
411 Mohammadi A. , Habibi D. , Rohami M. , and Mafakheri S. Effect of drought stress on antioxidant enzymes activity of some chickpea cultivars. Am.-Eurasian J. Agric. Environ. Sci. 2011, 11, 782785.
Molina C. , Rotter B. , Horres R. , Udupa S.M. , Besser B. , Bellarmino L. , Baum M. , Matsumura H. , Terauchi R. , Kahl G. , and Winter P. SuperSAGE: The drought stress-responsive transcriptome of chickpea roots. BMC Genomics 2008, 9, 553.
Molina C. , Zaman-Allah M. , Khan F. , Fatnassi N. , Horres R. , Rotter B. , Steinhauer D. , Amenc L. , Drevon J.J. , Winter P. , and Kahl G. The salt-responsive transcriptome of chickpea roots and nodules via deepSuperSAGE. BMC Plant Biol. 2011, 11, 31.
Naya L. , Ladrera R. , Ramos J. , Gonzalez E.M. , Arrese-Igor C. , Minchin F.R. , and Becana M. The responses of carbon metabolism and antioxidant defenses of alfalfa nodules to drought stress and to subsequent recovery of plants. Plant Physiol. 2007, 144, 11041114.
Nayyar H. , Singh S. , Kaur S. , and Kumar S. , Upadhyaya H.D. Differential sensitivity of Macrocarpa and Microcarpa types of chickpea (Cicer arietinum L.) to water stress: association of contrasting stress response with oxidative injury. J. Integr. Plant Biol. 2006a, 48, 13181329.
Nayyar H. , Kaur S. , Singh S. , and Upadhyaya H.D. Differential sensitivity of Desi (small-seeded) and Kabuli (large-seeded) chickpea genotypes to water stress during seed filling: Effects on accumulation of seed reserves and yield. J. Sci. Food Agric. 2006b, 86(13), 20762082.
Nguyen K.H. , Ha C.V. , Watanabe Y. , Tran U.T. , Nasr Esfahani M. , Nguyen D.V. , and Tran L.S. Correlation between differential drought tolerability of two contrasting drought-responsive chickpea cultivars and differential expression of a subset of CaNAC genes under normal and dehydration conditions. Front. Plant Sci. 2015, 6, 449.
Pace P.F. , Crale H.T. , El-Halawany S.H.M. , Cothren J.T. , and Senseman S.A. Drought induced changes in shoot and root growth of young cotton plants. J. Cotton Sci. 1999, 3, 183187.
Palta J.A. , Nandwal A.S. , Kumari S. , and Turner N.C. Foliar nitrogen applications increase the seed yield and protein content in chickpea (Cicer arietinum L.) subject to terminal drought. Aust. J. Agric. Res. 2005, 56, 105112.
Pandey A. , Chakraborty S. , Datta A. , and Chakraborty N. Proteomics approach to identify dehydration responsive nuclear proteins from chickpea (Cicer arietinum L). Mol. Cell. Proteomics 2008, 7, 88107.
Parween S. , Nawaz K. , Roy R. , Pole A.K. , Venkata Suresh B. , Misra G. , Jain M. , Yadav G. , Parida S.K. , Tyagi A.K. , Bhatia S. , and Chattopadhyay D. An advanced draft genome assembly of a desi type chickpea (Cicer arietinum L.). Sci. Rep. 2015, 5, 12806. doi:10.1038/srep12806.
Poltronieri P. , Bonsegna S. , De Domenico S. , and Santino A. Molecular mechanisms of abiotic stress response in plants. Field Veg. Crops Res./Ratarstvo Povrtartsvo 2011, 48, 1524.
Poltronieri P. , and Miwa M. and Hong Y. PARP proteins, NAD, epigenetics, and antioxidative response in abiotic stress. In: Poltronieri P. and Hong Y. Eds. Applied Plant Genomics and Biotechnology, pp. 237252, Chapter 15. Elsevier, Oxford, UK, 2015.
Poltronieri P , Taurino M , Bonsegna S , De Domenico S , Santino A. Monitoring the activation of jasmonate biosynthesis genes for selection of chickpea hybrids tolerant to drought stress. In: Chakraborty U. and Chakraborty B. Eds. Abiotic Stresses in Crop Plants, pp. 5470, Chapter 4. CABI, Wallingford, UK, 2015.
Poltronieri P. , Taurino M. , De Domenico S. , Bonsegna S. , and Santino A. Activation of the jasmonate biosynthesis pathway in roots in drought stress. In: Tuteja N. and Gill S.S. Eds. Climate Change and Abiotic Stress Tolerance, pp. 325342. Wiley-VCH GmbH & Co. KGaA, Weinheim, Germany, 2013.
Purushothaman R. and Krishnamurthy L. Timing of sampling for the canopy temperature depression can be critical for the b est differentiation of drought tolerance in chickpea. J. SAT Agric. Res. 2014, 12, 18.
Purushothaman R. , Krishnamurthy L. , Upadhyaya H.D. , Vadez V. , and Varshney R.K. Shoot traits and their relevance in terminal drought tolerance of chickpea (Cicer arietinum L.). Field Crops Res. 2016, 197, 1027. doi:10.1016/j.fcr.2016.07.016.
Purushothaman R. , Thudi, M. , Krishnamurthy L. , Upadhyaya, H.D. , Kashiwagi, J. , Gowda C.L.L. , and Varshney R.K. Association of mid-reproductive stage canopy temperature depression with the molecular markers and grain yields of chickpea (Cicer arietinum L.)

germplasm under terminal drought. Field Crops Res. 2015, 174, 111.

Purushothaman R. , Upadhyaya H.D. , Gaur P.M. , Gowda C.L.L. , and Krishnamurthy L. Kabuli and desi chickpeas differ in their requirement for reproductive duration. Field Crops Res. 2014, 163, 431.

Pushpavalli R. , Zaman-Allah M. , Turner N.C. , Baddam R. , Rao M.V. , and Vadez V. Higher flower and seed number leads to higher yield under water stress conditions imposed during reproduction in chickpea. Funct. Plant Biol. 2014, 42, 162174.

Ramalingam A. , Kudapa H. , Pazhamala L.T. , Garg V. , and Varshney R.K. Gene expression and yeast two-hybrid studies of 1R-MYB Transcription Factor mediating drought stress response in chickpea (Cicer arietinum L.). Front. Plant Sci. 2015, 6, 1117.

Ramos M.L.G. , Gordon A.J. , Minchen F.R. , Sprent J.I. , and Parsons R. Effect of water stress on nodule physiology and biochemistry of a drought tolerant cultivar of common bean (Phaseolus vulgaris L.). Ann. Bot. 1999, 83, 5763.

Sassi A.S., Aydi S., Gonzalez E.M., Abdelly C. Osmotic stress affects water relations, growth, and nitrogen fixation in Phaseolus vulgaris plants. Acta Physiol Plant 2008, 30, 441449.

Sassi S. , Aydi S. , Gonzalez E.M. , Arrese-Igor C. , and Abdelly C. Understanding osmotic stress tolerance in leaves and nodules of two Phaseolus vulgaris cultivars with contrasting drought tolerance. Symbiosis 2010, 52, 110.

Siddique K.H.M. , Regan K.L. , Tennant G. , and Thomson B.D. Water use and water use efficiency of cool season grain legumes in low rainfall Mediterranean-type environments. Eur. J. Agron. 2001, 15, 267280.

Singh G.D. , Wani A.A. , Kaur D. , and Sogi D.S. Characterisation and functional properties of proteins of some Indian chickpea (Cicer arietinum) cultivars. J. Sci. Food Agric. 2008, 88, 778786.

Sohrabi Y. , Heidari G. , Weisany W. , Ghasemi Golezani K. , and Mohammadi K. Som e physiological responses of chickpea cultivars to arbuscular mycorrhiza under drought stress. Russ. J. Plant Physiol. 2012, 59, 708716.

Szabados L. and Savour A. Proline: a multifunctional amino acid. Trends Plant Sci. 2009, 15, 8997.

412 Talbi C. , Sanchez C. , Hidalgo-Garcia A. , Gonzalez E.M. , Arrese-Igor C. , Girard L. , Bedmar E.J. , and Delgado M.J. Enhanced expression of Rhizobium etli cbb3 oxidase improves drought tolerance of common bean symbiotic nitrogen fixation. J. Exp. Bot. 2012, 63, 50355043.

Turner N.C. , Davies S.L. , Plummer J.A. , and Siddique K.H.M. Seed filling in grain legumes (pulses) under water deficits with emphasis on chickpea (Cicer arietinum L.). Adv. Agron. 2005, 87, 211250.

Ulemale C.S. , Mate S.N. , and Deshmukh D.V. Physiological indices for drought tolerance in chickpea (Cicer arietinum L.). World J. Agric. Sci. 2013, 9, 123.d131.d.

Varshney R.K. , Hiremath P.J. , Lekha P. , Kashiwagi J. , Balaji J. , Deokar A.A. , Vadez V. , Xiao Y. , Srinivasan R. , Gaur P.M. , Siddique K.H.M. , Town C.D. , and Hoisington D.A. A comprehensive resource of drought- and salinity responsive ESTs for gene discovery and marker development in chickpea (Cicer arietinum L.). BMC Genomics 2009, 10, 523.

Yaqoob M. , Hollington P.A. , Mahar A.B. , and Gurmani Z.A. Yield performance and responses studies of chickpea (Cicer arietinum L.) genotypes under drought stress. Emirates J. Food Agric. 2013, 25, 117123.

Zaman-Allah M. , Jenkinson D.M. , and Vadez V. A conservative pattern of water use, rather than deep or profuse rooting, is critical for the terminal drought tolerance of chickpea. J. Exp. Bot. 2011a, 62, 42394252.

Zaman-Allah M. , Jenkinson D.M. , and Vadez V. Chickpea genotypes contrasting for seed yield under terminal drought stress in the field differ for traits related to the control of water use. Funct. Plant Biol. 2011b, 38, 270281.