



Abiotic Stress Adaptation in Plants

Physiological, Molecular and Genomic Foundation

Ashwani Pareek · Sudhir K. Sopory
Hans J. Bohnert · Govindjee
Editors



Springer

Contents

Contents	vii
Preface	xv
Contributors	xix
The Editors	xxiii
Author Index	xxvii
Color Plates	xxix
1 Abiotic Tolerance and Crop Improvement	1
<i>Subrahmaniam Nagarajan and Shantha Nagarajan</i>	
I Introduction	2
II Types of Abiotic Stress in Plants	3
III High Temperature Stress	3
IV Cold and Frost Stress	6
V Water Deficit Stress	7
VI Water Logging Stress	8
VII Soil-Related Stresses	9
VIII Climate Change and Stress in Plants	10
IX Conclusions	11
Acknowledgements	11
References	11
Part I: Stress Perception and Signal Transduction	
2 Sensors and Signal Transducers of Environmental Stress in Cyanobacteria	15
<i>Yu Kanesaki, Dmitry. A. Los, Iwane Suzuki, and Norio Murata</i>	
I Introduction	16
II Potential Sensors and Signal Transducers in Cyanobacteria	17
III Involvement of Two-Component Regulatory Systems in Signal Perception and Transduction during Exposure to Environmental Stress	18
IV Other Potential Sensors and Transducers of Environmental Signals	25
V Conclusions and Perspectives	27
Acknowledgements	27
References	28

3	Stress Signaling I: The Role of Abscissic Acid (ABA)	33
	<i>Christopher D. Rock, Yoichi Sakata, and Ralph S. Quatrano</i>	
	I Introduction	35
	II Initial Perception of the Stress	35
	III ABA Receptors	36
	IV Transduction of the Stress Signal	39
	V Regulation of Abiotic Stresses at the Level of Gene Expression	44
	VI Responses to Temperature Stresses	46
	VII Cross-Talk Between Abiotic and Biotic Stress Responses	49
	VIII Regulation of ABA Metabolism	54
	Acknowledgements	57
	References	57
4	Stress Signaling II: Calcium Sensing and Signaling	75
	<i>Marie Boudsocq and Jen Sheen</i>	
	I Introduction	76
	II Calcium Signals	76
	III Calcium Sensing and Signaling	78
	IV Conclusions	86
	Acknowledgements	86
	References	86
5	Stress Signaling III: Reactive Oxygen Species (ROS)	91
	<i>Mikael Brosché, Saijallisa Kangasjärvi, Kirk Overmyer, Michael Wrzaczek, and Jaakko Kangasjärvi</i>	
	I Introduction	92
	II ROS Production and Control	92
	III The Perception of ROS	95
	IV Insights from Genetic and Genomic Strategies	97
	V Conclusions	99
	Acknowledgements	99
	References	100
6	A Biotic or Abiotic Stress?	103
	<i>Alexandre Robert-Seilaniantz, Rajendra Bari, and Jonathan D.G. Jones</i>	
	I Introduction	104
	II Biotic Stress Versus Abiotic Stress	105
	III General Stress Response	105
	IV ABA and Jasmonic Acid: Usual Suspects for Interaction	107
	V New Points of Interaction	109
	VI Conclusions	116
	Acknowledgements	117
	References	117

7	Protein Kinases and Phosphatases for Stress Signal Transduction in Plants	123
	<i>Lee Chae, Yong Hwa Cheong, Kyung-Nam Kim, Girdhar K Pandey, and Sheng Luan</i>	
	I Introduction	125
	II Receptor-Like Kinases	125
	III Mitogen Activated Protein (MAP) Kinases and MAPK Cascades	132
	IV Calcium-Activated Protein Kinases	138
	V Protein Phosphatases	145
	VI Conclusions	150
	Acknowledgements	150
	References	150
8	Nitrogen Source Influences Root to Shoot Signaling Under Drought	165
	<i>Jason Q.D. Goodger and Daniel P. Schachtman</i>	
	I Introduction	166
	II Nitrogen Source and Availability Influences Signaling Under Drought	166
	III Charge Balance in the Xylem Accounts for Changes Induced by Nutrition and Drought	169
	IV Ammonium and Nitrate Grown Plants: Changes in Xylem Sap Composition	170
	V Conclusions	172
	Acknowledgements	172
	References	172
Part II: Stress Regulation of Gene Expression		
9	Abiotic Stress Responses: Complexities in Gene Expression	177
	<i>Vaishali Panjabi-Sabharwal, Ratna Karan, Tanveer Khan, and Ashwani Pareek</i>	
	I Introduction	178
	II Signal Transduction Pathways Under Abiotic Stresses	179
	III Resources for Identification of Novel Genes	180
	IV Genomics-based Approaches for Understanding the Response of Plants Towards Abiotic Stresses	182
	V Interactome	192
	VI Future Prospects	194
	Acknowledgements	195
	References	195
10	Promoters and Transcription Factors in Abiotic Stress-Responsive Gene Expression	199
	<i>Kazuo Nakashima and Kazuko Yamaguchi-Shinozaki</i>	
	I Introduction	200
	II Significant ABA-Independent Gene Expression Under Abiotic Stress	201

III	Other ABA-Independent Gene Expression Under Abiotic Stress	206
IV	ABA-Responsive Gene Expression Under Abiotic Stresses	206
V	Other Types of ABA-Dependent Gene Expression Under Abiotic Stresses	209
VI	Conclusions and Future Perspectives	210
	Acknowledgements	211
	References	211

11 Epigenetic Regulation: Chromatin Modeling and Small RNAs **217**

Viswanathan Chinnusamy and Jian-Kang Zhu

I	Introduction	219
II	Epigenetics	219
III	Abiotic Stress-Induced Epigenetic Changes	230
IV	Conclusions and Perspectives	235
	Acknowledgements	236
	References	236

Part III: Physiology and Metabolism

12 Ion Homeostasis **245**

Anna Amtmann and Roger Leigh

I	Introduction	246
II	The Need for Ion Homeostasis in Salt Tolerance	246
III	Essential Components and Parameters of an 'Ion Homeostat'	247
IV	Strategies for Na ⁺ Homeostasis	251
V	Transporters Involved in Na ⁺ Homeostasis	253
VI	Conclusions and Outlook	257
	Acknowledgements	259
	References	259

13 Glutathione Homeostasis: Crucial for Abiotic Stress Tolerance in Plants **263**

Bhumesh Kumar, Sneh Lata Singla-Pareek, and Sudhir K. Sopory

I	Introduction	264
II	Regulation of Biosynthesis, Turnover and Compartmentation of Glutathione	265
III	Uptake and Transport of Glutathione	266
IV	Quantification of Redox Status and its Modulation by Abiotic Stresses	267
V	Changes in Glutathione Homeostasis in Plants Under Abiotic Stresses	267
VI	Protein Oxidation Under Abiotic Stresses	273
VII	Glutathione as Signaling Molecule and Role of Glutaredoxins	273
VIII	Crosstalk and Interaction with Other Biomolecules	276
IX	Conclusions and Perspectives	278
	Acknowledgements	278
	References	278

14 Water Balance and the Regulation of Stomatal Movements **283**

Christophe Belin, Sébastien Thomine, and Julian I. Schroeder

I	Introduction	284
II	How Does Water Balance Affect Stomatal Movements?	285

III	Mechanism of Stomatal Movements and Its Regulation by Water Balance	288
IV	Genes and Promoters of Interest to Manipulate Stomatal Function in Crop Plants	297
V	Conclusions	297
	Acknowledgements	298
	References	298

15 Responses to Macronutrient Deprivation 307

Arthur R. Grossman, David Gonzalez-Ballester, Nakako Shibagaki, Wirulda Pootakham, and Jeffrey Moseley

I	Introduction	309
II	Nitrogen Uptake and Assimilation	309
III	Responses to Sustained Nitrogen Starvation	316
IV	Sulfur Uptake and Assimilation	316
V	Control of Sulfur Starvation Responses	322
VI	Phosphate Uptake and Assimilation	327
VII	Control of Phosphorus Starvation Responses	330
VIII	Conclusions	334
	Acknowledgements	335
	References	335

16 Osmolyte Regulation in Abiotic Stress 349

Arun Lahiri Majumder, Sonali Sengupta, and Lily Goswami

I	Introduction	350
II	Osmolytes and their Types	350
III	Regulation of Osmolyte Concentration in Plants: Cell and Organ Level	354
IV	Role of Compatible Solutes/Osmolytes in Other Organisms and Animal Cells	358
V	Mechanism of Action of Osmolytes	361
VI	Unique Osmolytes: Glucosylglycerol/Diphosphoinositols	364
VII	Transgenics with Compatible Solutes for Salinity Stress Tolerance	365
VIII	Conclusions	367
	References	367

17 Programmed Cell Death in Plants 371

Avijit Das, Maki Kawai-Yamada, and Hirofumi Uchimiya

I	Introduction	372
II	Anatomy of Cell Death	373
III	Biochemistry of Cell Death	374
IV	Role of Vacuole	375
V	Role of Mitochondrion	375
VI	Role of Chloroplast	376
VII	Signals in Cell Death	377
VIII	Cell Death Regulator	378
IX	Conclusions	379
	References	379

Part IV: Overcoming Stress

18 Varietal Improvement for Abiotic Stress Tolerance in Crop Plants: Special Reference to Salinity in Rice **387**

Rakesh Kumar Singh, Edilberto Redoña, and Luzminda Refuerzo

I	Introduction	389
II	The Need for Abiotic Stress-Tolerant Cultivars	389
III	Past Breeding Efforts	390
IV	Limits of Plant Stress Tolerance	392
V	Breeding Salinity Tolerance with High Yield	393
VI	The Concept of Heritability	394
VII	Genetics of Salt Tolerance	396
VIII	Breeding Methodology	398
IX	Screening Methodology	401
X	Breeding Strategy to Enhance Salinity Tolerance Through Pyramiding of Mechanisms	405
XI	Testing Approaches for Varietal Adaptability	406
XII	Factors Affecting Salt Tolerance	408
XIII	Collaborative Research	409
XIV	Rice Varieties Developed for Salt Tolerance	410
XV	Impact of Salt-Tolerant Rice Varieties	411
XVI	Conclusions	411
XVII	Recommendations and Future Lines of Research	412
	References	412

19 Transgenic Approaches **417**

Anil K. Singh, Sudhir K. Sopory, Ray Wu, and Sneh L. Singla-Pareek

I	Introduction	418
II	Transgenic Approaches for Producing Abiotic Stress Tolerant Plants	419
III	Future Perspectives	438
	Acknowledgements	438
	References	438

20 Marker Assisted Breeding **451**

*Michael J. Thomson, Abdelbagi M. Ismail, Susan R. McCouch,
and David J. Mackill*

I	Introduction	452
II	Molecular Markers as Tools for Dissecting Quantitative Traits	453
III	Case Studies from a Model Crop: MAS for Abiotic Stress Tolerance in Rice	457
IV	Future Perspectives	462
V	Conclusions	465
	Acknowledgements	466
	References	466

21	Stress, Mutators, Mutations and Stress Resistance	471
	<i>Jonathan Gressel and Avraham A. Levy</i>	
I	Introduction-Stress Induced Changes in Mutation Frequency	472
II	Mutator Genes	472
III	Mutators in Stress Resistance – Implications	476
IV	Genetic, Circumstantial and Speculative Evidence for Mutators in Resistance to Stress	477
V	Can Stress Increase the Mutation Frequency to Resistance?	478
VI	Conclusions	480
	<i>Acknowledgements</i>	481
	<i>References</i>	481
22	Systems Biology of Abiotic Stress: The Elephant and the Blind Men	485
	<i>Nina V. Fedoroff</i>	
I	Introduction	486
II	First Responders: Stomatal Guard Cells	487
III	A Systems View of the Stress Response: The Elephant	490
IV	The Future	495
	<i>Acknowledgements</i>	495
	<i>References</i>	495
23	Global Climate Change, Stress and Plant Productivity	503
	<i>Altaf Ahmad, Hema Diwan, and Yash P. Abrol</i>	
I	<i>Introduction</i>	504
II	Elevated Carbon Dioxide	504
III	High Temperature	509
IV	Ultraviolet Radiation	514
V	Tropospheric Ozone	515
VI	Biotic Stress	515
VII	Conclusions and Future Prospects	516
	<i>Acknowledgements</i>	517
	<i>References</i>	517
	Subject Index	523