

Contents

List of Contributors *xiii*

Foreword *xix*

About the Book *xxi*

About the Editor *xxiii*

- 1 **Heat Tolerance in Cotton: Morphological, Physiological, and Genetic Perspectives** 1
Muhammad Tehseen Azhar, Shabir Hussain Wani, Muhammad Tanees Chaudhary, Tariq Jameel, Parwinder Kaur, and Xiongming Du
- 1.1 Introduction 1
- 1.1.1 Morphological and Physiological Traits 2
- 1.1.1.1 Seedling and Root Growth 3
- 1.1.1.2 Stomatal Conductance 3
- 1.1.1.3 Cell Membrane Thermostability 4
- 1.1.1.4 Canopy Temperature 5
- 1.1.1.5 Chlorophyll Content 6
- 1.1.2 Genetics and Molecular Basis of Heat Tolerance in Cotton 8
- 1.1.3 Conventional Breeding Approaches 9
- 1.1.4 Modern Molecular Breeding Approaches 10
- 1.2 Conclusion and Future Prospects 12
- References 12

2	Seed Priming as a Method to Generate Heat-stress Tolerance in Plants: A Minireview	23
	<i>Aditya Banerjee and Aryadeep Roychoudhury</i>	
2.1	Introduction	23
2.2	Mechanism of Heat Stress Injury in Plants	24
2.3	Seed Priming Generating Heat-stress Tolerance	26
2.4	Conclusion	27
2.5	Future Perspectives	27
	Acknowledgments	28
	References	28
3	How Effective Are Stress-associated Proteins in Augmenting Thermotolerance?	33
	<i>Inès Karmous and Sandeep Kumar Verma</i>	
3.1	Introduction	33
3.1.1	Heat Shock Proteins (HSPs)	34
3.1.2	Proline	36
3.1.3	Dehydrins (DHNs)	37
3.1.4	Role of Metabolic Proteins in Thermotolerance	37
3.2	Conclusion	40
	References	40
4	Biochemical and Molecular Markers: Unraveling Their Potential Role in Screening Germplasm for Thermotolerance	47
	<i>Ahmed Ismail, Kareem A. Mosa, Muna A. Ali, and Mohamed Helmy</i>	
4.1	Introduction	47
4.2	Types of Markers	48
4.3	Morphological Markers	49
4.4	Molecular Markers	49
4.5	Biochemical Markers	53
4.6	Quantitative Trait Loci for Plant Thermotolerance	54
4.7	Plant Metabolites Under Heat Stress	61
4.8	Antioxidant Enzymes and Heat Stress	63
4.9	Conclusion	68
	References	70

5	Alteration in Carbohydrate Metabolism Modulates Thermotolerance of Plant under Heat Stress 77
	<i>Roseline Xalxo, Bhumika Yadu, Jipsi Chandra, Vibhuti Chandrakar, and S. Keshavkant</i>
5.1	Introduction 77
5.1.1	Heat Stress and Thermotolerance 79
5.1.1.1	Morphological Alterations 80
5.1.1.2	Anatomical Alterations 80
5.1.1.3	Physiological and Biochemical Modifications 81
5.1.1.4	Cell Membrane Integrity 82
5.2	Carbohydrate as Protectives Molecules 83
5.2.1	Osmolyte 83
5.2.2	Thermoprotectant 84
5.3	Carbohydrates as Signaling Molecules 85
5.3.1	Reproductive Cell Development 85
5.3.2	Seed Development 86
5.3.3	Seed Germination and Yield Loss 87
5.4	Adverse Impacts of Heat Stress 87
5.4.1	Photosynthesis 87
5.4.1.1	Altered Carbon Assimilation 88
5.4.1.2	Chlorophyll Breakdown 88
5.4.2	Major and Minor Carbohydrate Metabolism 89
5.4.3	Expression of Regulatory Genes 89
5.4.4	Enzyme Activity 90
5.5	Mechanisms Involved in Thermotolerance 93
5.5.1	Glucose and Heat-stress Tolerance 93
5.5.2	Sucrose and Heat-stress Tolerance 94
5.5.3	Fructan and Heat-stress Tolerance 95
5.5.4	Trehalose and Heat-stress Tolerance 96
5.5.5	Raffinose and Heat-stress Tolerance 97
5.6	Genetic Approaches/Strategies for Improving Thermotolerance 97
5.6.1	Genetically Modified Crop Production 97
5.6.2	Transgenic Strategies 99
5.7	Conclusions and Future Perspectives 102
	References 103

6	Transcriptomics to Dissect Plant Responses to Heat Stress 117
	<i>Sagar Satish Datir</i>
6.1	Introduction 117
6.1.1	Transcriptome Sequencing and Expression Profiling of Genes Involved in Heat Stress Response—119
6.1.1.1	Rice (<i>Oryza sativa</i> L.) 119
6.1.1.2	Wheat (<i>Triticum aestivum</i> L.) 123
6.1.1.3	Maize (<i>Zea mays</i> L.) 125
6.1.1.4	Switchgrass (<i>Panicum virgatum</i> L.) and Ryegrass (<i>Lolium perenne</i> L.) 126
6.1.1.5	Spinach (<i>Spinacia oleracea</i> L.) 128
6.1.1.6	<i>Brassica rapa</i> L. 129
6.1.1.7	Banana (<i>Musa acuminata</i> Colla) 130
6.2	Conclusions 131
	References 132
7	Proteomics as a Tool for Characterizing the Alteration in Pathways Associated with Defense and Metabolite Synthesis 141
	<i>Reetika Mahajan and Sajad Majeed Zargar</i>
7.1	Introduction 141
7.2	What Is Proteomics? 142
7.3	Need of Proteomics in Post-genomic Era 143
7.4	Different Branches of Proteomics 143
7.5	Techniques Used in Quantitative Proteomics 145
7.5.1	Gel-based and Gel-free Methods 146
7.5.2	Label-based and Label-free Methods 149
7.6	Role of Proteomics in Studying Alteration in Pathways Associated with Defense and Metabolite Synthesis 150
7.7	Conclusion and Future Perspective 156
	References 156
8	RNA World and Heat Stress Tolerance in Plants 167
	<i>Usman Ijaz, Muhammad Amjad Ali, Habibullah Nadeem, Lin Tan, and Farrukh Azeem</i>
8.1	Introduction 167
8.2	Plant microRNAs 168

8.3	Small Interfering RNA (siRNA)	177
8.4	Long Noncoding RNAs (lncRNAs)	178
8.5	Circular RNAs (circRNAs)	179
8.6	Conclusions and Future Perspectives	180
	References	180
9	Heat Shock Proteins: Master Players for Heat-stress Tolerance in Plants during Climate Change	189
	<i>Annu Yadav, Jitender Singh, Koushlesh Ranjan, Pankaj Kumar, Shivani Khanna, Madhuri Gupta, Vinay Kumar, Shabir Hussain Wani, and Anil Sirohi</i>	
9.1	Introduction	189
9.2	Classification of HSPs	192
9.2.1	HSP100	192
9.2.1.1	Structure of HSP100	192
9.2.1.2	Mode of Action: The HSP100 Chaperone Cycle	192
9.2.2	HSP90	195
9.2.2.1	Structure of HSP90	197
9.2.2.2	Mode of Action: The HSP90 Chaperone Cycle	197
9.2.3	HSP70	198
9.2.3.1	Structure of HSP70	198
9.2.3.2	Mode of Action: The Hsp70 Chaperone Cycle	198
9.2.4	HSP60	199
9.2.4.1	Structure of HSP60	201
9.2.4.2	Mode of Action: The Hsp60 Chaperone Cycle	201
9.2.5	The Small Heat Shock Protein Family (sHSPs)	202
9.2.5.1	Structure of sHSP	202
9.2.5.2	Mode of Action: Small Heat Shock Proteins	203
9.3	HSPs Expression Under Heat Stress Condition	203
9.4	Conclusion and Future Prospects	205
	References	205
10	The Contribution of Phytohormones in Plant Thermotolerance	213
	<i>Sonal Mishra, Mansi Bhardwaj, Shakti Mehrotra, Aksar Ali Chowdhary, and Vikas Srivastava</i>	
10.1	Introduction	213
10.2	Protectants in Heat Stress Alleviation	215
10.2.1	Osmolytes	215

10.2.2	Nutrients	215
10.2.3	Signaling Molecules	217
10.2.4	Polyamines	217
10.2.5	Phytohormones	218
10.3	Application of Hormones in HT Management	218
10.3.1	Auxin	219
10.3.2	Gibberellin	221
10.3.3	Cytokinin	222
10.3.4	Abscisic Acid	224
10.3.5	Ethylene	225
10.3.6	Salicylic Acid	225
10.3.7	Jasmonic Acid	227
10.3.8	Brassinosteroid	228
10.4	Conclusion and Prospects	229
	Acknowledgements	229
	References	230
11	Exploring In-built Defense Mechanisms in Plants under Heat Stress	239
	<i>Giridara Kumar Surabhi and Jatindra Kumar Seth</i>	
11.1	Introduction	239
11.2	Effect of Heat Stress on Crop Plants	240
11.2.1	Heat Stress Effects on Physiology and Cell Structures	241
11.2.2	Heat Stress Effects on Vegetative Stages	242
11.2.3	Heat Stress Effects on Reproductive Stage	243
11.2.4	Heat Stress Effects on Yield	243
11.3	Threshold Temperature	244
11.4	In-built Defense System in Plants to Overcome High Temperature Stress	245
11.4.1	Accumulation of Thermoprotectants	245
11.4.1.1	Heat Shock Proteins (HSPs)	245
11.4.1.2	Proline	246
11.4.1.3	Glycinebetaine (GB)	248
11.4.1.4	Abscisic Acid (ABA)	249
11.4.1.5	Salicylic Acid (SA)	250
11.4.1.6	Heat Stress Effects on Secondary Metabolism	255
11.4.2	Transcriptional Regulation	256

11.4.3	Role of Small RNAs (miRNAs) in Heat-stress Tolerance	258
11.5	Conclusion	261
	Acknowledgement	262
	References	263
	Index	283