

Parvaiz Ahmad · M.N.V. Prasad *Editors*

Abiotic Stress Responses in Plants

Metabolism, Productivity
and Sustainability

 Springer

Editors

Parvaiz Ahmad
Department of Botany
Amar Singh College
University of Kashmir
Srinagar, Jammu and Kashmir
India
parvaizbot@rediffmail.com

M.N.V. Prasad
Department of Plant Sciences
University of Hyderabad
Andhra Pradesh, Hyderabad
India
prasad_mnv@yahoo.com
mnvsl@uohyd.ernet.in

ISBN 978-1-4614-0633-4 e-ISBN 978-1-4614-0634-1

DOI 10.1007/978-1-4614-0634-1

Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2011940823

© Springer Science+Business Media, LLC 2012

All rights reserved. This work may not be translated or copied in whole or in part without the written permission of the publisher (Springer Science+Business Media, LLC, 233 Spring Street, New York, NY 10013, USA), except for brief excerpts in connection with reviews or scholarly analysis. Use in connection with any form of information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed is forbidden.

The use in this publication of trade names, trademarks, service marks, and similar terms, even if they are not identified as such, is not to be taken as an expression of opinion as to whether or not they are subject to proprietary rights.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Parvaiz Ahmad • M.N.V. Prasad
Editors

Abiotic Stress Responses in Plants

Metabolism, Productivity
and Sustainability

 Springer

Contents

1 Abiotic Stress Responses in Plants: Present and Future.....	1
Nitin Mantri, Vikas Patade, Suprasanna Penna, Rebecca Ford, and Edwin Pang	
2 Abiotic Stress-Induced Morphological and Anatomical Changes in Plants.....	21
Angelos Patakas	
3 Abiotic Stress Responses in Plants: Metabolism to Productivity.....	41
Andrea Furtado Macedo	
4 Approaches to Increasing Salt Tolerance in Crop Plants.....	63
Ratna Karan and Prasanta K. Subudhi	
5 Understanding and Exploiting the Impact of Drought Stress on Plant Physiology.....	89
Olga M. Grant	
6 Sustainable Fruit Production in Mediterranean Orchards Subjected to Drought Stress.....	105
Adriano Sofo, Assunta Maria Palese, Teresa Casacchia, Bartolomeo Dichio, and Cristos Xiloyannis	
7 Drought Stress Induced Reactive Oxygen Species and Anti-oxidants in Plants.....	131
S.M. Impa, S. Nadaradjan, and S.V.K. Jagadish	
8 Role of Glutathione Reductase in Plant Abiotic Stress.....	149
Peerzada Yasir Yousuf, Khalid Ul Rehman Hakeem, Ruby Chandna, and Parvaiz Ahmad	
9 Flavonoids as Antioxidants in Plants Under Abiotic Stresses.....	159
Martina Di Ferdinando, Cecilia Brunetti, Alessio Fini, and Massimiliano Tattini	

10	Proteomic Markers for Oxidative Stress: New Tools for Reactive Oxygen Species and Photosynthesis Research	181
	Ruby Chandna, Khalid Ul Rehman Hakeem, and Parvaiz Ahmad	
11	Environmental Stress and Role of Arbuscular Mycorrhizal Symbiosis	197
	Anna Fusconi and Graziella Berta	
12	Effects of Exogenous Application of 5-Aminolevulinic Acid in Crop Plants.....	215
	Ahmet Korkmaz	
13	Abiotic Stress and Role of Salicylic Acid in Plants	235
	Miyuki Hara, Jun Furukawa, Aiko Sato, Tsuyoshi Mizoguchi, and Kenji Miura	
14	Trehalose and Abiotic Stress Tolerance	253
	Miguel López-Gómez and Carmen Lluch	
15	Uptake of Mineral Elements During Abiotic Stress	267
	Fatih Duman	
16	Effect of Micronutrient Deficiencies on Plants Stress Responses	283
	R. Hajiboland	
17	Stress-Induced Flowering.....	331
	Kiyotoshi Takeno	
18	Postharvest Stress Treatments in Fruits and Vegetables	347
	Yoshihiro Imahori	
19	Abscisic Acid Signaling in Plants.....	359
	Radomira Vankova	
20	Plant Tolerance and Fatty Acid Profile in Responses to Heavy Metals.....	369
	Asiya Hameed, Tabasum N. Qadri, Mahmooduzzafar, and T.O. Siddiqi	
21	Cd Accumulation and Subcellular Distribution in Plants and Their Relevance to the Trophic Transfer of Cd	387
	M.S. Monteiro and A.M.V.M. Soares	
22	The Role of Soil Organic Matter in Trace Element Bioavailability and Toxicity	403
	Gabrijel Ondrasek and Zed Rengel	
23	Oxidative Stress and Phytoremediation.....	425
	Kinga Drzewiecka, Mirosław Mleczek, Agnieszka Waśkiewicz, and Piotr Goliński	

24 Phytoremediation of Low Levels of Heavy Metals Using Duckweed (<i>Lemna minor</i>).....	451
Lué-Merú Marcó Parra, Gosmyr Torres, Adolfo David Arenas, Erick Sánchez, and Korina Rodríguez	
Index.....	465

Contributors

Parvaiz Ahmad

Department of Botany, A.S. College, University of Kashmir, Srinagar,
Jammu & Kashmir, India

Adolfo David Arenas

Dpto. de Química y Suelos, Decanato de Agronomía,
Universidad Centroccidental Lisandro Alvarado, Cabudare, Venezuela

Graziella Berta

Dipartimento di Scienze dell'Ambiente e della Vita,
Università del Piemonte Orientale "Amedeo Avogadro", Alessandria, Italy

Cecilia Brunetti

Department of Plant, Soil and Environmental Science,
University of Florence, Sesto Fiorentino, Firenze, Italy

Teresa Casacchia

CRA, Centro di Ricerca per l'Olivicoltura e l'Industria Olearia, Rende,
Cosenza, Italy

Ruby Chandna

Molecular Ecology Lab, Department of Botany, Jamia Hamdard,
Hamdard Nagar, New Delhi, India

National Institute for Plant Genomics and Research, New Delhi, India

Bartolomeo Dichio

Dipartimento di Scienze dei Sistemi Colturali, Forestali e dell'Ambiente,
Università degli Studi della Basilicata, Potenza, Italy

Kinga Drzewiecka

Department of Chemistry, University of Life Sciences, Poznań, Poland

Fatih Duman

Department of Biology, Faculty of Science, Erciyes University,
Kayseri, Turkey

Martina Di Ferdinando

Department of Plant, Soil and Environmental Science,
University of Florence, Sesto Fiorentino, Firenze, Italy

Alessio Fini

Department of Plant, Soil and Environmental Science,
University of Florence, Sesto Fiorentino, Firenze, Italy

Rebecca Ford

Department of Agriculture and Food Systems, Melbourne School of Land
and Environment, The University of Melbourne, Parkville, VIC, Australia

Jun Furukawa

Graduate School of Life and Environmental Sciences,
University of Tsukuba, Tsukuba, Japan

Anna Fusconi

Dipartimento di Biologia Vegetale, Università degli Studi di Torino,
Torino, Italy

Piotr Goliński

Department of Chemistry, University of Life Sciences, Poznań, Poland

Olga M. Grant

Department of Biology, National University of Ireland, Maynooth,
Co. Kildare, Ireland

R. Hajiboland

Plant Science Department, University of Tabriz, Tabriz, Iran

Khalid Ul Rehman Hakeem

Molecular Ecology Lab, Department of Botany, Jamia Hamdard,
Hamdard Nagar, New Delhi, India

Asiya Hameed

Department of Botany, Jamia Hamdard, Hamdard Nagar, New Delhi, India

Miyuki Hara

Graduate School of Life and Environmental Sciences,
University of Tsukuba, Tsukuba, Japan

Yoshihiro Imahori

Graduate School of Life and Environmental Sciences,
Osaka Prefecture University, Osaka, Japan

S.M. Impa

Crop and Environmental Sciences Division, International Rice
Research Institute, Metro Manila, Philippines

S.V. K. Jagadish

Crop and Environmental Sciences Division, International Rice
Research Institute, Metro Manila, Philippines

Ratna Karan

School of Plant, Environmental, and Soil Sciences, Louisiana State
University Agricultural Center, Baton Rouge, LA, USA

Ahmet Korkmaz

Department of Horticulture, Faculty of Agriculture,
Kahramanmaraş Sutcu Imam University, Kahramanmaraş, Turkey

Carmen Lluch

Departamento de Fisiología Vegetal, Facultad de Ciencias,
Universidad de Granada, Granada, Spain

Miguel López-Gómez

Departamento de Fisiología Vegetal, Facultad de Ciencias,
Universidad de Granada, Granada, Spain

Andrea Furtado Macedo

Laboratório Integrado de Biologia Vegetal, Departamento de Botânica,
Instituto de Biociências, CCBS, Universidade Federal do Estado do Rio
de Janeiro, Rio de Janeiro, RJ, Brazil

Mahmooduzzafar

Department of Botany, Jamia Hamdard, Hamdard Nagar, New Delhi, India

Nitin Mantri

School of Applied Sciences, Health Innovations Research Institute,
RMIT University, Melbourne, VIC, Australia

Kenji Miura

Graduate School of Life and Environmental Sciences,
University of Tsukuba, Tsukuba, Japan

Tsuyoshi Mizoguchi

Graduate School of Life and Environmental Sciences,
University of Tsukuba, Tsukuba, Japan

Mirosław Mleczek

Department of Chemistry, University of Life Sciences, Poznań, Poland

M.S. Monteiro

CESAM and Department of Biology, University of Aveiro, Aveiro, Portugal

S. Nadaradjan

Crop Physiology Unit, Department of Plant Breeding and Genetics,
Pandit Jawaharlal Nehru College of Agriculture and Research Institute,
Karaikal, Puducherry, India

Gabrijel Ondrasek

Faculty of Agriculture, University of Zagreb, Zagreb, Croatia

Assunta Maria Palese

Dipartimento di Scienze dei Sistemi Culturali, Forestali e dell'Ambiente,
Università degli Studi della Basilicata, Potenza, Italy

Edwin Pang

School of Applied Sciences, Health Innovations Research Institute,
RMIT University, Melbourne, VIC, Australia

Lué-Merú Marcó Parra

Dpto. de Química y Suelos, Decanato de Agronomía,
Universidad Centroccidental Lisandro Alvarado, Cabudare, Venezuela

Vikas Patade

Defence Research and Development Organisation,
Defence Institute of Bio-Energy Research, Goraparao, Uttarakhand, India

Angelos Patakas

Laboratory of Plant Production, University of Ioannina, Agrinio, Greece

Suprasanna Penna

Functional Plant Biology Section, Nuclear Agriculture and Biotechnology
Division, Bhabha Atomic Research Centre, Trombay, Mumbai, India

Tabasum N. Qadri

Department of Botany, Jamia Hamdard, Hamdard Nagar, New Delhi, India

Zed Rengel

School of Earth and Environment, University of Western Australia,
Crawley, WA, Australia

Korina Rodríguez

Dpto. de Química y Suelos, Decanato de Agronomía,
Universidad Centroccidental Lisandro Alvarado, Cabudare, Venezuela

Erick Sánchez

Dpto. de Química y Suelos, Decanato de Agronomía,
Universidad Centroccidental Lisandro Alvarado, Cabudare, Venezuela

Aiko Sato

Graduate School of Life and Environmental Sciences,
University of Tsukuba, Tsukuba, Japan

T.O. Siddiqi

Department of Botany, Jamia Hamdard, Hamdard Nagar, New Delhi, India

A.M.V.M. Soares

CESAM and Department of Biology, University of Aveiro, Aveiro, Portugal

Adriano Sofo

Dipartimento di Scienze dei Sistemi Culturali, Forestali e dell'Ambiente,
Università degli Studi della Basilicata, Potenza, Italy

Prasanta K. Subudhi

School of Plant, Environmental, and Soil Sciences, Louisiana State
University Agricultural Center, Baton Rouge, LA, USA

Kiyotoshi Takeno

Department of Biology, Faculty of Science, Niigata University, Ikarashi,
Niigata, Japan

Massimiliano Tattini

Consiglio Nazionale delle Ricerche, Istituto per la Protezione delle Piante,
Sesto Fiorentino, Firenze, Italy

Gosmyr Torres

Dpto. de Química y Suelos, Decanato de Agronomía,
Universidad Centroccidental Lisandro Alvarado, Cabudare, Venezuela

Radomira Vankova

Laboratory of Hormonal Regulations in Plants, Institute of Experimental Botany AS CR, Prague, The Czech Republic

Agnieszka Waśkiewicz

Department of Chemistry, University of Life Sciences, Poznań, Poland

Cristos Xiloyanni

Dipartimento di Scienze dei Sistemi Culturali, Forestali e dell'Ambiente, Università degli Studi della Basilicata, Potenza, Italy

Peerzada Yasir Yousuf

Molecular Ecology Lab, Department of Botany, Jamia Hamdard, Hamdard Nagar, New Delhi, India

Preface

Climate constrained world represents an ideal scenario of abiotic stresses in which there has been a change in the statistical distribution of weather (temperature, soil moisture, salinity, ecohydrology, soil fertility, emission of greenhouse gases, etc.) over periods of time that range from decades to centuries to millions of years. Plants do respond to these changes in the process of acclimation and acquiring tolerance – morphologically, structurally, physiologically, biochemical and molecular mechanisms.

Abiotic stress cause changes in soil–plant–atmosphere continuum which is responsible for reduced yield in several of the major crops in different parts of the world. Therefore, the subject of abiotic stress response in plants – metabolism, productivity and sustainability is gaining considerable significance in the contemporary world.

This is a collective and companion volume to our previous edition *Environmental Adaptations and Stress Tolerance of Plants in the Era of Climate Change*. This volume deals with an array topics in the broad area of abiotic stress responses in plants focusing “*metabolism, productivity and sustainability*” by selecting some of the widely investigated themes. Chapter 1: Abiotic stress responses in plants – present and future. Chapter 2: Abiotic stress-induced morphological and anatomical changes in plants. Chapter 3: Abiotic stress responses in plants – metabolism to productivity. Chapter 4: Approaches to increasing salt tolerance in crop plants. Chapter 5: Understanding and exploiting the impact of drought stress on plant physiology. Chapter 6: Sustainable fruit production in Mediterranean orchards subjected to drought stress. Chapter 7: Drought stress-induced reactive oxygen species and antioxidants in plants. Chapter 8: Role of glutathione reductase in plant abiotic stress. Chapter 9: Flavonoids as antioxidants in plants under abiotic stresses. Chapter 10: Proteomic markers for oxidative stress – new tools for reactive oxygen species and photosynthesis research. Chapter 11: Environmental stress and role of arbuscular mycorrhizal symbiosis. Chapter 12: Effects of exogenous application of 5-aminolevulinic acid (ALA) in crop plants. Chapter 13: Abiotic stress and role of salicylic acid in plants. Chapter 14: Trehalose and abiotic stress tolerance. Chapter 15: Uptake of mineral elements during abiotic stress. Chapter 16: Effect of micronutrient deficiencies on plants stress responses. Chapter 17: Stress-induced flowering. Chapter 18: Postharvest stress treatments in fruits and vegetables. Chapter 19: Abscisic acid signalling in plants. Chapter 20: Plant tolerance and fatty acid profile in

responses to heavy metals. Chapter 21: Cadmium accumulation and subcellular distribution in plants and their relevance to the trophic transfer of Cd. Chapter 22: The role of soil organic matter in trace element bioavailability and toxicity. Chapter 23: Oxidative stress and phytoremediation. Chapter 24: Phytoremediation of low levels of heavy metals using duckweed (*Lemna minor*). We fervently believe that this volume will provide good information and understanding of abiotic stress tolerance in plants.

We are extremely thankful to all the contributors for comprehensive and cogent reviews which ultimately resulted in the present form. We are pleased to place on record the superb and skillful job of Amna Ahmad, Andy Kwan and the rest of the technical team at the production unit for publishing this work in record time.

Srinagar, Jammu & Kashmir, India
Hyderabad, Andhra Pradesh, India

Parvaiz Ahmad
M.N.V. Prasad