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

Parvaiz Ahmad • M.N.V. Prasad
Editors

Abiotic Stress Responses in Plants

Metabolism, Productivity and Sustainability

Springer

Contents

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,
Kahramanmaras Sutcu Imam University, Kahramanmaras, 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 Colturali, 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 Colturali, 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 Colturali, 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 Parvaiz Ahmad
Hyderabad, Andhra Pradesh, India M.N.V. Prasad