
Volume 2
Reactive Oxyg
Nitrogen an
Species in
Production, Metabolism, S
and Defense Mechanism
Edited by
Mirza Hasanuzzaman | Vasile
Kamrun Nahar | Masayuki F
H2O2
Volume 1
Reactive Oxygen,
Nitrogen and Sulfur
Species in Plants
Production, Metabolism, Signaling
and Defense Mechanisms
Edited by
Mirza Hasanuzzaman | Vasileios Fotopoulos
Kamrun Nahar | Masayuki Fujita
NO
H2O2
H2S
WILEY Blackwell
Reactive Oxygen, Nitrogen and
Sulfur Species in Plants
Volume 1

Reactive Oxygen, Nitrogen and Sulfur Species in Plants

Reactive Oxygen, Nitrogen and Sulfur Species in Plants

Production, Metabolism, Signaling and Defense Mechanisms

Volume 1

Edited by

Mirza Hasanuzzaman
Sher-e-Bangla Agricultural University
Dhaka
Bangladesh

Vasileios Fotopoulos
Cyprus University of Technology
Lemesos
Cyprus

Kamrun Nahar
Sher-e-Bangla Agricultural University
Dhaka
Bangladesh

Masayuki Fujita
Kagawa University
Japan

WILEY Blackwell

This edition first published 2019

Registered Offices
John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Library of Congress Cataloging-in-Publication Data

Names: Hasanuzzaman, Mirza, editor.
Title: Reactive oxygen, nitrogen and sulfur species in plants : production, metabolism, signaling and defense mechanisms / edited by Mirza Hasanuzzaman, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, Vasileios Fotopoulos, Cyprus University of Technology, Lemesos, Cyprus, Kamrun Nahar, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, Masayuki Fujita, Kagawa University, Japan.
Description: Hoboken, NJ : Wiley-Blackwell, [2019] | Two volumes in one. | Includes bibliographical references and index. |
Identifiers: LCCN 2019000084 (print) | LCCN 2019000951 (ebook) | ISBN 9781119468660 (Adobe PDF) | ISBN 9781119468646 (ePub) | ISBN 9781119468691 (hardcover)
Subjects: LCSH: Plants–Effect of stress on–Molecular aspects. | Plant cellular signal transduction. | Oxidative stress.
Classification: LCC QK725 (ebook) | LCC QK725 .R4295 2019 (print) | DDC 571.7/42–dc23
LC record available at https://lccn.loc.gov/2019000084

Cover Design: Wiley
Cover Image: © molekuul_be/Shutterstock, © molekuul_be/Shutterstock, © oticki/Shutterstock, © extender_01/Shutterstock, © Anton-Burakov/Shutterstock

Set in 10/12pt Warnock by SPi Global, Pondicherry, India

10 9 8 7 6 5 4 3 2 1

Contents

About the Editors

Dr. Mirza Hasanuzzaman is Professor of Agronomy at Sher-e-Bangla Agricultural University in Dhaka. He received his PhD on "Plant Stress Physiology and Antioxidant Metabolism" from Ehime University, Japan with a scholarship from the Japanese government. Later, he completed his postdoctoral research at the Center of Molecular Biosciences, University of the Ryukyus, Japan, as a recipient of the Japan Society for the Promotion of Science (JSPS) postdoctoral fellowship. He was also the recipient of the Australian Government's Endeavor Research Fellowship for postdoctoral research as an Adjunct Senior Researcher at the University of Tasmania, Australia. Dr. Hasanuzzaman's current work is focused on the physiological and molecular mechanisms of environmental stress tolerance (salinity, drought, flood, and heavy metals/metalloids). Dr. Hasanuzzaman has published over 100 articles in peer-reviewed journals. He has edited six books and written 30 book chapters on important aspects of plant physiology, plant stress tolerance, and crop production. According to Scopus®, Dr. Hasanuzzaman's publications have received over 3000 citations with an h-index of 30 and an i10-index of 55. He is an editor and reviewer for more than 50 peer-reviewed international journals and was a recipient of the "Publons Peer Review Award 2017 and 2018." He has been honored by different authorities for to his outstanding performance in different fields like research and education, and he has received the World Academy of Science Young Scientist Award (2014). He has presented 25 papers, abstracts, and posters at international conferences in several countries (USA, UK, Germany, Australia, Japan, Austria, Sweden, Russia, etc.). Dr. Hasanuzzaman is a member of 40 professional societies and is the acting Publication Secretary of the Bangladesh Society of Agronomy and the Bangladesh JSPS Alumni Association. He is a fellow of The Linnean Society of London.

Dr. Vasileios Fotopoulos is Associate Professor in Structural and Functional Plant Biology and head of the CUT Plant Stress Physiology Group established in 2008 (HYPERLINK "http://www.plant-stress.weebly.com"www.plant-stress.weebly.com). His main scientific research focuses on the study of nitro-oxidative signaling cascades involved in the plant's response to stress factors, while emphasis is being given in the development of chemical treatment technologies towards the amelioration of abiotic stress factors and promotion of plant growth. To date, Dr. Fotopoulos is the author of 62 scientific papers published in peer-reviewed journals (h-index=23; Source: Scopus), as well as 7 book chapters. He currently serves as Associate Editor in BMC Plant Biology, Gene and five other journals. He has also been assigned to evaluate competitive research proposals from different countries (France, Belgium, Poland, Chile, Latvia, Greece, Italy, Portugal, Israel, Qatar, Austria, Cyprus, Denmark), EU proposals (EUROSTARS), while he is an active Review Panel Member for COST Actions (EU) in the field of 'Natural Sciences'. Finally, he has acted as examiner of MSc theses/PhD dissertations from Italy, South Africa and The Netherlands.

Dr. Kamrun Nahar is Associate Professor, Department of Agricultural Botany at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. She obtained BSc Ag (Hons.) and MS in Agricultural Botany from Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. She persued her second MS degree in 2013 from Kagawa University, Japan. She also received her PhD Degree on "Environmental Stress Physiology of Plants" in 2016 from the United Graduate School of Agricultural Sciences, Ehime University, Japan with a Japanese Government (MEXT) Scholarship. She started her career as a Lecturer in the Department of Agricultural Botany, Sher-e-Bangla Agricultural University in February 2010, was promoted to Assistant Professor in 2012 and to Associate Professor in 2017. Dr. Nahar has been involved in research with field crops emphasizing stress physiology since 2006. She has completed several research works and is also continuing a research project funded by Sher-e-Bangla Agricultural University Research System and Ministry of Science and Technology (Bangladesh). She is supervising MS students. Dr. Nahar published number of articles in peer-reviewed journals and books of reputed publishers. She has published 50 articles and chapters related to plant physiology and environmental stresses with Springer, Elsevier, CRC Press, Wiley, etc. Her publications reached about 2000 citations with h-index: 22 (according to Scopus). She is involved in editorial activities and reviewer of international journals. She is an active member of about 20 professional societies.

Dr. Masayuki Fujita is Professor in the Laboratory of Plant Stress Responses, Faculty of Agriculture, Kagawa University, Kagawa, Japan. He received his BSc in Chemistry from Shizuoka University, Shizuoka, and M Ag and PhD in plant biochemistry from Nagoya University, Nagoya, Japan. His research interests include physiological, biochemical, and molecular biological responses based on secondary metabolism in plants under various abiotic and biotic stresses; phytoalexin, cytochrome P450, glutathione *S*-transferase, and phytochelatin; and redox reaction and antioxidants. In the last decade his works have focused on oxidative stress and antioxidant defense in plants under environmental stress. His group investigates the role of different exogenous protectants in enhancing antioxidant defense and methylglyoxal detoxification systems in plants. He has supervised 4 MS students and 13 PhD students as main supervisor. He has about 150 publications in journal and books and has edited 10 books.

List of Contributors

Shakeel Ahmad
Department of Agronomy
Faculty of Agricultural Sciences and Technology
Bahauddin Zakariya University
Multan
Punjab
Pakistan

Haseen Ahmed
Laboratory of Photobiology and Molecular Microbiology
Center of Advanced Study in Botany
Institute of Science
Banaras Hindu University
Varanasi
Uttar Pradesh
India

Niaz Ahmed
Department of Soil Science
Faculty of Agricultural Sciences and Technology
Bahauddin Zakariya University
Multan
Punjab
Pakistan

Melina Amenta
Laboratorio de Bioquímica Vegetal y Microbiana
Facultad de Cs. Agrarias
Universidad Nacional de Mar del Plata
Balcarce
Argentina

Mehmood Ali Noor
Institute of Crop Science
Key Laboratory of Crop Physiology and Ecology
Chinese Academy of Agricultural Sciences
Beijing
China

Muhammad Arif Ali
Department of Soil Science
Faculty of Agricultural Sciences and Technology
Bahauddin Zakariya University
Multan
Punjab
Pakistan

Muhammad Arshad
Institute of Environmental Sciences and Engineering
School of Civil and Environmental Engineering
National University of Sciences and Technology
Islamabad
Islamabad Capital Territory
Pakistan

Y.S. Bakakina
Institute of Biophysics and Cell Engineering of the National Academy of Sciences of Belarus
Minsk
Belarus

Alma Balestrazzi
Department of Biology and Biotechnology 'L. Spallanzani'
University of Pavia
Pavia
Italy

Shagun Bali
Department of Botanical and Environmental Sciences
Guru Nanak Dev University
Amritsar
Punjab
India
and
Institute of Food Biotechnology and Genomics
National Academy of Sciences of Ukraine
Kyiv
Ukraine

Aditya Banerjee
Department of Biotechnology
St. Xavier's College (Autonomous)
Kolkata
West Bengal
India

María Belén Fernández
Instituto de Investigaciones Biológicas
Facultad de Ciencias Exactas y Naturales
Universidad Nacional de Mar del Plata-Consejo Nacional de Investigaciones Científicas y Técnicas
Mar del Plata
Argentina

Renu Bhardwaj
Department of Botanical and Environmental Sciences
Guru Nanak Dev University
Amritsar
Punjab
India
and
Institute of Food Biotechnology and Genomics
National Academy of Sciences of Ukraine
Kyiv
Ukraine

Yaroslav B. Blume
Institute of Food Biotechnology and Genomics
National Academy of Sciences of Ukraine
Kyiv
Ukraine

Raúl Cassia
Instituto de Investigaciones Biológicas
Facultad de Ciencias Exactas y Naturales
Universidad Nacional de Mar del Plata-Consejo Nacional de Investigaciones Científicas y Técnicas
Mar del Plata
Argentina

Debasis Chakrabarty
Genetics and Molecular Biology Division
CSIR – National Botanical Research Institute
Lucknow
Uttar Pradesh
India

Zalán Czékus
Department of Plant Biology
University of Szeged
Szeged
Hungary
and
Doctoral School in Biology
Faculty of Science and Informatics
University of Szeged
Szeged
Hungary

Valeria Dávila
Laboratorio de Zoonosis Parasitarias
Facultad de Ciencias Exactas y Naturales
Universidad Nacional de Mar del Plata
Mar del Plata
Argentina

Sarita Devi
Department of Botany and Plant Physiology
CCS Haryana Agricultural University
Hisar
Haryana
India

L.V. Dubovskaya
Institute of Biophysics and Cell Engineering of the National Academy of Sciences of Belarus
Minsk
Belarus

Savita Duhan
Department of Botany and Plant Physiology
CCS Haryana Agricultural University
Hisar
Haryana
India

Füsun Eyidoğan
Department of Elementary Education
Baskent University
Ankara
Turkey

Shah Fahad
Department of Agriculture
The University of Swabi
Swabi
Khyber Pakhtunkhwa
Pakistan

Esmat Farouk Ali
Department of Horticulture (Floriculture)
Faculty of Agriculture
Assuit University
Assuit
Egypt

Chiara Forti
Department of Biology and Biotechnology 'L. Spallanzani'
University of Pavia
Pavia
Italy

Andrea Galatro
Universidad Nacional de La Plata.
La Plata
Argentina
and
CONICET-Universidad Nacional de La Plata
Instituto de Fisiología Vegetal (INFIVE)
La Plata
Argentina

Pedro García-Caparrós
Department of Agronomy
University of Almeria
Agrifood Campus of International Excellence ceiA3
Almería
La Cañada de San Urbano
Spain

Vandana Gautam
Department of Botanical and Environmental Sciences
Guru Nanak Dev University
Amritsar
Punjab
India

Jarosław Gocławski
Institute of Applied Computer Science
Lodz University of Technology
Lodz
Poland

Vinod Goyal
Department of Botany and Plant Physiology
CCS Haryana Agricultural University
Hisar
Haryana
India

Carla Gualtieri
Department of Biology and Biotechnology 'L. Spallanzani'
University of Pavia
Pavia
Italy

Idrees Haider
Department of Soil Science
Faculty of Agricultural Sciences and Technology
Bahauddin Zakariya University
Multan
Punjab
Pakistan

Neha Handa
Department of Botanical and Environmental Sciences
Guru Nanak Dev University
Amritsar
Punjab
India

Mirza Hasanuzzaman
Department of Agronomy
Faculty of Agriculture
Sher-e-Bangla Agricultural University
Dhaka
Bangladesh

Sajjad Hussain
Department of Horticulture
Faculty of Agricultural Sciences and Technology
Bahauddin Zakariya University
Multan
Punjab
Pakistan

Muhammad Ilyas
Department of Agronomy
Faculty of Crop Production Sciences
University of Agriculture Peshawar
Peshawar
Khyber Pakhtunkhwa
Pakistan

Shivam Jasrotia
Department of Zoology
Guru Nanak Dev University
Amritsar
Punjab
India
and
Institute of Food Biotechnology and Genomics
National Academy of Sciences of Ukraine
Kyiv
Ukraine

Vinod K. Kannaujiya
Department of Botany
MMV
Banaras Hindu University
Varanasi
Uttar Pradesh
India

Mahima Karthikeyan
Department of Biotechnology
Bharathiar University
Coimbatore
Tamil Nadu
India

Ravinderjit Kaur
Department of Zoology
Guru Nanak Dev University
Amritsar
Punjab
India
and
Institute of Food Biotechnology and Genomics
National Academy of Sciences of Ukraine

Kyiv
Ukraine

Ceyhun Kayıhan
Department of Molecular Biology and Genetics
Baskent University
Ankara
Turkey

Anjali Khajuria
Department of Zoology
Guru Nanak Dev University
Amritsar
Punjab
India
and
Institute of Food Biotechnology and Genomics
National Academy of Sciences of Ukraine
Kyiv
Ukraine

Kanika Khanna
Department of Botanical and Environmental Sciences
Guru Nanak Dev University
Amritsar
Punjab
India

Deepak Kumar
Laboratory of Photobiology and Molecular Microbiology
Center of Advanced Study in Botany
Institute of Science
Banaras Hindu University
Varanasi
Uttar Pradesh
India

Vinod Kumar
Department of Botany
DAV University
Jalandhar, Punjab
India

Anita Kumari
Department of Botany and Plant Physiology
CCS Haryana Agricultural University
Hisar
Haryana, India

Elżbieta Kuźniak
Department of Plant Physiology and Biochemistry
Faculty of Biology and Environmental Protection
University of Lodz
Lodz
Poland

Manohar Lal
Department of Botany and Plant Physiology
CCS Haryana Agricultural University
Hisar
Haryana
India

María Teresa Lao
Department of Agronomy
University of Almeria
Agrifood Campus of International Excellence ceiA3
Almería
La Cañada de San Urbano
Spain

Anca Macovei
Department of Biology and Biotechnology 'L. Spallanzani'
University of Pavia
Pavia
Italy

Mohamed Magdy F. Mansour
Department of Botany
Faculty of Science
Ain Shams University
Cairo
Egypt

Panchanand Mishra
Centre for Education
Central University of Jharkhand
Ranchi
Jharkhand
India
and
Department of Botany
Simdega College
Simdege
Jharkhand
India

Eliana Molina-Moya
Department of Biochemistry and Cellular and Molecular Biology of Plants
Estación Experimental del Zaidín (CSIC)
Granada
Spain

Renu Munjal
Department of Botany and Plant Physiology
CCS Haryana Agricultural University
Hisar
Haryana
India

Macarena Nocioni
Instituto de Investigaciones Biológicas
Facultad de Ciencias Exactas y Naturales
Universidad Nacional de Mar del Plata-Consejo Nacional de Investigaciones Científicas y Técnicas
Mar del Plata
Argentina

Puja Ohri
Department of Zoology
Guru Nanak Dev University
Amritsar
Punjab
India

Attila Ördög
Department of Plant Biology
University of Szeged
Szeged
Hungary

Jainendra Pathak
Laboratory of Photobiology and Molecular Microbiology
Center of Advanced Study in Botany
Institute of Science
Banaras Hindu University
Varanasi
Uttar Pradesh
India

Andrea Pagano
Department of Biology and Biotechnology 'L. Spallanzani'
University of Pavia
Pavia
Italy

Leyre Pescador-Azofra
Department of Biochemistry and Cellular and Molecular Biology of Plants
Estación Experimental del Zaidín (CSIC)
Granada
Spain

Pooja
Department of Botany and Plant Physiology
CCS Haryana Agricultural University
Hisar
Haryana
India

Péter Poór
Department of Plant Biology
University of Szeged
Szeged
Hungary

Susana Puntarulo
Facultad de Farmacia y Bioquímica
Fisicoquímica
Universidad de Buenos Aires
Buenos Aires
Argentina