

# **Sustainable Development and Biodiversity**

Volume 20

## **Series editor**

Kishan Gopal Ramawat

Botany Department, M.L. Sukhadia University, Udaipur, India

This book series provides complete, comprehensive and broad subject based reviews about existing biodiversity of different habitats and conservation strategies in the framework of different technologies, ecosystem diversity, and genetic diversity. The ways by which these resources are used with sustainable management and replenishment are also dealt with. The topics of interest include but are not restricted only to sustainable development of various ecosystems and conservation of hotspots, traditional methods and role of local people, threatened and endangered species, global climate change and effect on biodiversity, invasive species, impact of various activities on biodiversity, biodiversity conservation in sustaining livelihoods and reducing poverty, and technologies available and required. The books in this series will be useful to botanists, environmentalists, marine biologists, policy makers, conservationists, and NGOs working for environment protection.

More information about this series at <http://www.springer.com/series/11920>

Vijay Rani Rajpal · Deepmala Sehgal  
Avinash Kumar · S. N. Raina  
Editors

# Genetic Enhancement of Crops for Tolerance to Abiotic Stress: Mechanisms and Approaches, Vol. I

*Editors*

Vijay Rani Rajpal  
Department of Botany  
Hansraj College  
University of Delhi  
Delhi, India

Deepmala Sehgal  
CIMMYT Headquarters  
El Batán, Veracruz, Mexico

Avinash Kumar  
Vinoba Bhawe University  
Hazaribag, Jharkhand, India

S. N. Raina  
Amity Institute of Biotechnology  
Amity University  
Noida, Uttar Pradesh, India

ISSN 2352-474X

ISSN 2352-4758 (electronic)

Sustainable Development and Biodiversity

ISBN 978-3-319-91955-3

ISBN 978-3-319-91956-0 (eBook)

<https://doi.org/10.1007/978-3-319-91956-0>

Library of Congress Control Number: 2018951914

© Springer Nature Switzerland AG 2019, corrected publication 2019

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

## Preface: Volume I

The changing climate change scenarios have gripped humanity for a long time and are expected to worsen in the coming decades. Agriculture is already feeling the effects of climate change by reduced crop productivity, heavy yield losses, scarcity of water for farming, reduced rate of precipitation, and the list goes on. In staple crops, particularly wheat, rice, maize, soybean, barley, and sorghum, research has shown about 30% of the yearly variation in agricultural yields due to changes in rainfall and temperature.

Of all the threats that agriculture is exposed to due to climate change, abiotic stresses such as drought (water deficit), extreme temperatures (cold, frost, and heat), and/or salinity (sodicity) are the most devastating ones, causing more than 50% of crop yield losses. Mineral (metal and metalloid) toxicity is an additional abiotic factor, which is becoming a big threat for both major and minor crops. Thus, improving tolerance to these abiotic stresses is a global plant breeding target. A lot of research has been conducted to investigate plants' responses to these stresses at the structural, physiological, transcriptional, and molecular level and on the resistance mechanisms allowing them to adapt and survive these stressful events. A major research target has also been cross talk among various mechanisms, in case of multiple stresses faced by plants.

Precise analysis of proteome and metabolome is essential for understanding the fundamentals of stress physiology and biochemistry. Scientists have utilized 'omics' platforms to unravel the influence of abiotic stresses on levels of different protein groups and metabolite classes and to pinpoint candidate genes underneath. In addition, chromatin modifications, nucleosome positioning, and DNA methylation have been recognized as important components in plants' adaptations to stresses. The potential of improving stress tolerance in crops by enhancing the stress memory through the activation of priming responses or the targeted modification of the epigenome has been a burning research topic.

This book provides a consolidated and an updated account of the research being conducted in above-mentioned areas by plant scientists all over the world. It is an invaluable resource for researchers and educators in the areas of tools and technologies to unravel plant's responses to abiotic stresses. The outcomes presented on

staple crops will be useful to a broad community of scientists working in similar areas and can provide useful leads to build strategies to generate abiotic stress tolerant varieties. Students will find this book handy to clear their concepts and to get an update on the research conducted in various crops at one place.

New Delhi, India  
El Batán, Mexico  
Hazaribag, India  
Noida, India

Vijay Rani Rajpal  
Deepmala Sehgal  
Avinash Kumar  
S. N. Raina

---

The original version of the book was revised: Book editor's affiliation has been updated in Copyright page. The correction to the book is available at [https://doi.org/10.1007/978-3-319-91956-0\\_12](https://doi.org/10.1007/978-3-319-91956-0_12)

# Acknowledgements

We sincerely thank all authors not only for agreeing to contribute chapters despite their hectic schedules and other work commitments but also for putting in their sincere efforts in providing up-to-date information. We are thankful to Prof. K. G. Ramawat for inspiring us to take up this assignment. All the three editors, Vijay Rani Rajpal, Deepmala Sehgal, and Avinash Kumar are thankful to their Mentor and Guide Prof. S. N. Raina for guidance and inspiration always. Vijay Rani Rajpal is also thankful to the two other co-editors for their active involvement from inception to compilation and editing process through the course of this book. The book would not have been possible without their active involvement and whole-hearted support. The editors Deepmala Sehgal and Avinash Kumar are also thankful to senior editors Profs. S. N. Raina and Vijay Rani Rajpal who had been their teachers and Ph.D. supervisors too for providing them the great opportunity to be an editor.

Last but not least, editors gratefully acknowledge their families for their understanding, patience, and emotional support. Our sincere thanks to the whole Springer team who was tirelessly involved in the production process. We particularly appreciate Dr. Valeria and Dr. Ineke for their continued support.

We are very hopeful that this book will attract readers who are crop scientists and to even undergraduates and postgraduates of agricultural universities and institutes that are interested in the genetic improvement of crop plants using modern tools.

# Contents

<b>1</b>	<b>Functional Genomics Approach Towards Dissecting Out Abiotic Stress Tolerance Trait in Plants</b> . . . . .	<b>1</b>
	Rohit Joshi, Brijesh K. Gupta, Ashwani Pareek, Mohan B. Singh and Sneha L. Singla-Pareek	
<b>2</b>	<b>Plant miRNAome: Cross Talk in Abiotic Stressful Times</b> . . . . .	<b>25</b>
	Prashanti Patel, Karuna Yadav, T. R. Ganapathi and Suprasanna Penna	
<b>3</b>	<b>Epigenetic Response of Plants to Abiotic Stress: Nature, Consequences and Applications in Breeding</b> . . . . .	<b>53</b>
	Manoj K. Dhar, Rahul Sharma, Parivartan Vishal and Sanjana Kaul	
<b>4</b>	<b>Effect of Drought Stress and Utility of Transcriptomics in Identification of Drought Tolerance Mechanisms in Maize</b> . . . . .	<b>73</b>
	Nidhi Singh, Shikha Mittal and Neelam Thirunavukkarasu	
<b>5</b>	<b>Physiological and Molecular Basis of Abiotic Stress Tolerance in Wheat</b> . . . . .	<b>99</b>
	H. M. Mamrutha, Rajender Singh, Davinder Sharma, Karnam Venkatesh, Girish Chandra Pandey, Rakesh Kumar, Ratan Tiwari and Indu Sharma	
<b>6</b>	<b>Molecular Chaperones: Key Players of Abiotic Stress Response in Plants</b> . . . . .	<b>125</b>
	Suchismita Roy, Manjari Mishra, Om Prakash Dhankher, Sneha L. Singla-Pareek and Ashwani Pareek	
<b>7</b>	<b>Role of Chromatin Assembly and Remodeling in Water Stress Responses in Plants</b> . . . . .	<b>167</b>
	Shoib Ahmad Baba, Deepti Jain and Nasheeman Ashraf	

<b>8</b>	<b>The ‘Omics’ Approach for Crop Improvement Against Drought Stress</b> . . . . .	<b>183</b>
	Deepti Jain, Nasheeman Ashraf, J. P. Khurana and M. N. Shiva Kameshwari	
<b>9</b>	<b>Genomic Strategies for Improving Abiotic Stress Tolerance in Crop Plants</b> . . . . .	<b>205</b>
	Jyoti Taunk, Asha Rani, Richa Singh, Neelam R. Yadav and Ram C. Yadav	
<b>10</b>	<b>Genomics of Arsenic Stress Response in Plants</b> . . . . .	<b>231</b>
	Smita Kumar and Prabodh Kumar Trivedi	
<b>11</b>	<b>Phytohormones Regulating the Master Regulators of CBF Dependent Cold Stress Signaling Pathway</b> . . . . .	<b>249</b>
	Prakriti Kashyap and Renu Deswal	
	<b>Correction to: Genetic Enhancement of Crops for Tolerance to Abiotic Stress: Mechanisms and Approaches, Vol. I</b> . . . . .	<b>C1</b>
	Vijay Rani Rajpal, Deepmala Sehgal, Avinash Kumar and S. N. Raina	
	<b>Index</b> . . . . .	<b>265</b>

# Contributors

**Nasheeman Ashraf** Plant Biotechnology Division, CSIR-Indian Institute of Integrative Medicine, Srinagar, Jammu and Kashmir, India

**Shoib Ahmad Baba** Plant Biotechnology Division, CSIR-Indian Institute of Integrative Medicine, Srinagar, Jammu and Kashmir, India

**Renu Deswal** Molecular Plant Physiology and Proteomics Laboratory, Department of Botany, University of Delhi, Delhi, India

**Om Prakash Dhankher** Stockbridge School of Agriculture, University of Massachusetts, Amherst, MA, USA

**Manoj K. Dhar** Genome Research Laboratory, School of Biotechnology, University of Jammu, Jammu, India

**T. R. Ganapathi** Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre, Mumbai, India

**Brijesh K. Gupta** Plant Stress Biology, International Centre for Genetic Engineering and Biotechnology, New Delhi, India

**Deepti Jain** Department of Plant Molecular Biology, Interdisciplinary Centre for Plant Genomics, Delhi University, South Campus, New Delhi, India; Department of Botany, Bangalore University, Bangalore, India

**Rohit Joshi** Plant Stress Biology, International Centre for Genetic Engineering and Biotechnology, New Delhi, India

**Prakriti Kashyap** Molecular Plant Physiology and Proteomics Laboratory, Department of Botany, University of Delhi, Delhi, India

**Sanjana Kaul** Genome Research Laboratory, School of Biotechnology, University of Jammu, Jammu, India

**J. P. Khurana** Department of Plant Molecular Biology, Interdisciplinary Centre for Plant Genomics, Delhi University, New Delhi, India

**Rakesh Kumar** ICAR-Indian Institute of Wheat and Barley Research, Karnal, India

**Smita Kumar** CSIR-National Botanical Research Institute, Council of Scientific and Industrial Research (CSIR-NBRI), Lucknow, India

**H. M. Mamrutha** ICAR-Indian Institute of Wheat and Barley Research, Karnal, India

**Manjari Mishra** School of Life Sciences, Jawaharlal Nehru University, New Delhi, India

**Shikha Mittal** Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi, India

**Girish Chandra Pandey** Department of Bioscience and Biotechnology, Banasthali University, Banasthali, India

**Ashwani Pareek** Stress Physiology and Molecular Biology Laboratory, School of Life Sciences, Jawaharlal Nehru University, New Delhi, India

**Prashanti Patel** Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre, Mumbai, India

**Suprasanna Penna** Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre, Mumbai, India

**Asha Rani** Department of Molecular Biology, Biotechnology and Bioinformatics, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India

**Suchismita Roy** School of Life Sciences, Jawaharlal Nehru University, New Delhi, India

**Davinder Sharma** ICAR-Indian Institute of Wheat and Barley Research, Karnal, India

**Indu Sharma** ICAR-Indian Institute of Wheat and Barley Research, Karnal, India

**Rahul Sharma** Genome Research Laboratory, School of Biotechnology, University of Jammu, Jammu, India

**M. N. Shiva Kameshwari** Department of Botany, Bangalore University, Bangalore, India

**Mohan B. Singh** Plant Molecular Biology and Biotechnology Laboratory, University of Melbourne, Parkville, VIC, Australia

**Nidhi Singh** Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi, India

**Rajender Singh** ICAR-Indian Institute of Wheat and Barley Research, Karnal, India

**Richa Singh** Department of Molecular Biology, Biotechnology and Bioinformatics, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India

**Sneh L. Singla-Pareek** Plant Stress Biology, International Centre for Genetic Engineering and Biotechnology, New Delhi, India

**Jyoti Taunk** Department of Molecular Biology, Biotechnology and Bioinformatics, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India

**Nepolean Thirunavukkarasu** Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi, India

**Ratan Tiwari** ICAR-Indian Institute of Wheat and Barley Research, Karnal, India

**Prabodh Kumar Trivedi** CSIR-National Botanical Research Institute, Council of Scientific and Industrial Research (CSIR-NBRI), Lucknow, India

**Karnam Venkatesh** ICAR-Indian Institute of Wheat and Barley Research, Karnal, India

**Parivartan Vishal** Genome Research Laboratory, School of Biotechnology, University of Jammu, Jammu, India

**Karuna Yadav** Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre, Mumbai, India

**Neelam R. Yadav** Department of Molecular Biology, Biotechnology and Bioinformatics, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India

**Ram C. Yadav** Department of Molecular Biology, Biotechnology and Bioinformatics, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India