

Salicylic Acid

Shamsul Hayat · Aqil Ahmad
Mohammed Nasser Alyemeni
Editors

Salicylic Acid

Plant Growth and Development

 Springer

Editors

Shamsul Hayat
Department of Botany
Aligarh Muslim University
Aligarh
India

Aqil Ahmad
Department of Botany
Aligarh Muslim University
Aligarh
India

and

Department of Botany and Microbiology
College of Science
King Saud University
Riyadh
Saudi Arabia

Mohammed Nasser Alyemeni
Department of Botany and Microbiology
College of Science
King Saud University
Riyadh
Saudi Arabia

ISBN 978-94-007-6427-9 ISBN 978-94-007-6428-6 (eBook)
DOI 10.1007/978-94-007-6428-6
Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2013935996

© Springer Science+Business Media Dordrecht 2013

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. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law. 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.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

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

*Dedicated to
the Institutions and Nations
Where We Work*

Preface

The healthy plant canopy that we recognise is the result of integrated metabolic functions administered by a number of factors, including hormones, of which six (Auxins, Gibberellins, Cytokinins, Abscissic acid, Ethylene and Brassinosteroids) are well recognised for their regulatory functions. However, the others (Salicylic acid, Polyamines and Jasmonates) can not be excluded from the list of hormones because of their well-recognised involvement in plant metabolism and growth.

This book is providing recent information related with Salicylic acid (SA), that was first noticed to be a major component in the extract from *Salix* (willow) bark and was used as an anti-inflammatory drug. It belongs to the phenolic group and is ubiquitous in plants. SA is involved in signal transduction, pondering over the plant resistance to stress and generates significant impact on photosynthesis, transpiration, uptake and transport of ions and plant growth and development. However, the observations related with this presumed plant hormone are very much scattered. It was, therefore, decided to compile all in the form of a book, based on 16 chapters written by various experts, working in this field. A total of 47 experts have explained their results based on the practical work carried over by them and of others on various selected aspects of plants under stress. After going through these chapters it may be concluded that this hormone has a wide range of actions mediated through genes and/or the cell membranes and can be grouped as a stress hormone. It is the second revised edition of the book.

With great pleasure, we extend our sincere thanks to all the contributors for their timely preparation of excellent and up-to-date contributions and also for their consistent support and cooperation. The first two editors (Hayat and Ahmad) are thankful to Aligarh Muslim University, Aligarh, India that gave us the employment and the seat to work. Whereas, Hayat and Alyemeni are also thankful to King Saud University, Riyadh, Saudi Arabia for their present assignment. Thanks are also due to Springer, The Netherlands for expeditious acceptance of our proposal and completion of the review process. Subsequent cooperation and understanding of their staff, especially, Malanie van Overbeek, publishing assistant, is also gratefully acknowledged.

We express our sincere thanks to the members of our family for all the support they provided and the neglect, what so ever, they suffered during the preparation of this book.

Finally we are thankful to the Almighty God.

Shamsul Hayat
Aqil Ahmad
Mohammed Nasser Alyemeni

Contents

1 Salicylic Acid: An Update on Biosynthesis and Action in Plant Response to Water Deficit and Performance Under Drought	1
Hanna Bandurska	
2 Salicylic Acid: Physiological Roles in Plants	15
Mohammad Yusuf, Shamsul Hayat, Mohammed Nasser Alyemeni, Qazi Fariduddin and Aqil Ahmad	
3 Salicylic Acid and Phospholipid Signaling	31
Beatriz A. Rodas-Junco, J. Armando Muñoz-Sánchez and S. M. Teresa Hernández-Sotomayor	
4 Transport of Salicylic Acid and Related Compounds	43
J.-L. Bonnemain, J.-F. Chollet and F. Rocher	
5 Interplay Between Environmental Signals and Endogenous Salicylic Acid Concentration	61
L. V. Kurepin, K. P. Dahal, M. Zaman and R. P. Pharis	
6 Impact of Salicylic Acid on the Transport and Distribution of Sugars in Plants	83
M. S. Krasavina and N. A. Burmistrova	
7 Endogenous ABA as a Hormonal Intermediate in the Salicylic Acid Induced Protection of Wheat Plants Against Toxic Ions	119
F. M. Shakirova, M. V. Bezrukova and D. R. Maslennikova	

8 Salicylic Acid Biosynthesis and Role in Modulating Terpenoid and Flavonoid Metabolism in Plant Responses to Abiotic Stress.	141
T. Tounekti, I. Hernández and S. Munné-Bosch	
9 Salicylic Acid-Mediated Stress-Induced Flowering.	163
K. C. Wada and K. Takeno	
10 Salicylic Acid-Mediated Abiotic Stress Tolerance	183
M. Pál, G. Szalai, V. Kovács, O. K. Gondor and T. Janda	
11 Signaling Role of Salicylic Acid in Abiotic Stress Responses in Plants	249
Tomonori Kawano, Takuya Hiramatsu and François Bouteau	
12 The Interplay Between Salicylic and Jasmonic Acid During Phytopathogenesis	277
Antonina V. Sorokan, Guzel F. Burkhanova and Igor V. Maksimov	
13 Potential Benefits of Salicylic Acid in Food Production	299
R. Martín-Mex, A. Nexticapán-Garcez and A. Larqué-Saavedra	
14 Short and Long Term Effects of Salicylic Acid on Protection to Phytoplasma Associated Stress in Potato Plants	315
H. A. López-Delgado, M. E. Mora-Herrera, R. Martínez-Gutiérrez and S. Sánchez-Rojo	
15 Efficiency of Salicylic Acid Application on Postharvest Perishable Crops	339
S. Supapvanich and S. Promyou	
16 Recent Advances and Future Prospects on Practical Use of Salicylic Acid.	357
L. P. Popova	
Index	387

Contributors

Aqil Ahmad Plant Physiology Section, Department of Botany, Aligarh Muslim University, Aligarh 202002, India

Mohammed Nasser Alyemeni Department of Botany and Microbiology, College of Science, King Saud University, Riyadh 11451, Saudi Arabia

Hanna Bandurska Department of Plant Physiology, Poznań University of Life Sciences, Wołyńska 35, 60-637 Poznan, Poland

M. V. Bezrukova Ufa Scientific Centre, Institute of Biochemistry and Genetics, Russian Academy of Sciences, pr. Octyabrya 71, Ufa 450054, Russia

J.-L. Bonnemain Laboratoire Écologie et Biologie des Interactions, Université de Poitiers, Unité Mixte de Recherche CNRS 7267, 40 avenue du Recteur Pineau, 86022 Poitiers Cedex, France

François Bouteau Institut de Biologie des Plantes, LEM, Université Paris Diderot-Paris 7, Bât 630, 91405 Orsay Cedex, France; LINV Kitakyushu Research Center, Kitakyushu, Japan; International Plant Neurobiology Laboratory, University of Florence, Sesto Fiorentino, Italy

F. Burkhanova Guzel Laboratory of the Biochemistry of Plant Immunity, Ufa Science Centre, Institute of Biochemistry and Genetics, Russian Academy of Sciences, pr. Oktyabrya 71, Ufa 450075, Russia

N. A. Burmistrova Timiryazev Institute of Plant Physiology, Russian Academy of Science, Botanicheskaya ul. 35, Moscow, Russia

J.-F. Chollet Institut de Chimie des Milieux et des Matériaux de Poitiers, Université de Poitiers, Unité Mixte de Recherche CNRS 7285, 40 avenue du Recteur Pineau, 86022 Poitiers Cedex, France

K. P. Dahal Department of Biological Sciences, University of Toronto Scarborough, Toronto, ON M1C 1A4, Canada

Qazi Fariduddin Plant Physiology Section, Department of Botany, Aligarh Muslim University, Aligarh 202002, India

O. K. Gondor Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, Martonvásár, POB. 19, 2462, Hungary

Shamsul Hayat Plant Physiology Section, Department of Botany, Aligarh Muslim University, Aligarh 202002, India; Department of Botany and Microbiology, King Saud University, Riyadh 11451, Saudi Arabia

I. Hernandez Facultat de Biologia, Departament de Biologia Vegetal, Universitat de Barcelona, Avinguda Diagonal 643, 08028 Barcelona, Spain

S. M. Teresa Hernandez-Sotomayor Unidad de Bioquímica y Biología Molecular de Plantas, Centro de Investigación Científica de Yucatán, Calle 43#130 Col, Chuburná de Hidalgo, 97200 Mérida, Yucatán, Mexico

Takuya Hiramatsu Faculty and Graduate School of Environmental Engineering, The University of Kitakyushu, Kitakyushu, Japan

T. Janda Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, Martonvásár, POB. 19, 2462, Hungary

Tomonori Kawano Faculty and Graduate School of Environmental Engineering, The University of Kitakyushu, Kitakyushu, Japan; Institut de Biologie des Plantes, LEM, Université Paris Diderot-Paris 7, Bât 630, 91405 Orsay Cedex, France; LINV Kitakyushu Research Center, Kitakyushu, Japan; International Plant Neurobiology Laboratory, University of Florence, Sesto Fiorentino, Italy

V. Kovacs Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, Martonvásár, POB. 19, 2462, Hungary

M. S. Krasavina Timiryazev Institute of Plant Physiology, Russian Academy of Science, Botanicheskaya ul. 35, Moscow, Russia

L. V. Kurepin Department of Biology, Western University, London, ON N6A 5B7, Canada

A. Larque-saavedra Centro de Investigación científica de Yucatán, A.C., Calle 43 No. 130, Chuburná de Hidalgo, 97200 Mérida, Yucatán, Mexico

H. A. Lopez-Delgado Programa Nacional de Papa, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP), Conjunto SEDAGRO, 52140 Metepec, México, Mexico

V. Maksimov Igor Laboratory of the Biochemistry of Plant Immunity, Ufa Science Centre, Institute of Biochemistry and Genetics, Russian Academy of Sciences, pr. Oktyabrya 71, Ufa 450075, Russia

R. Martinez-Gutierrez Programa Nacional de Papa, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP), Conjunto SEDAGRO, 52140 Metepec, México, Mexico

R. Martin-Mex Centro de Investigación científica de Yucatán, A.C., Calle 43 No. 130, Chuburná de Hidalgo, 97200 Mérida, Yucatán, Mexico

D. R. Maslennikova Ufa Scientific Centre, Institute of Biochemistry and Genetics, Russian Academy of Sciences, pr. Octyabrya 71, Ufa 450054, Russia

M. E. Mora-Herrera Centro Universitario Tenancingo, Universidad Autónoma del Estado de México, Carretera. Tenancingo-Villa Guerrero Km 1.5 Estado de, 52400 México, Mexico

S. Munne-Bosch Facultat de Biologia, Departament de Biologia Vegetal, Universitat de Barcelona, Avinguda Diagonal 643, 08028 Barcelona, Spain

J. Armando Munoz-Sanchez Unidad de Bioquímica y Biología Molecular de Plantas, Centro de Investigación Científica de Yucatán, Calle 43#130 Col, Chuburná de Hidalgo, 97200 Mérida, Yucatán, Mexico

A. Nexticapan-Garcez Centro de Investigación científica de Yucatán, A.C., Calle 43 No. 130, Chuburná de Hidalgo, 97200 Mérida, Yucatán, Mexico

M. Pal Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, Martonvásár, POB. 19, 2462, Hungary

R. P. Pharis Department of Biological Sciences, University of Calgary, Calgary, AB T2N 1N4, Canada

L. P. Popova Institute of Plant Physiology, Bulgarian Academy of Sciences, acad. G. Bonchev str, bl. 21, 1113 Sofia, Bulgaria

S. Promyou Faculty of Natural Resources and Agro-Industry, Kasetsart University, Chalermphrakiat Sakon Nakhon province campus, Sakon Nakhon province 47000, Thailand; Postharvest Technology Innovation Center, Commission on Higher Education, Bangkok 10400, Thailand

F. Rocher Institut de Chimie des Milieux et des Matériaux de Poitiers, Université de Poitiers, Unité Mixte de Recherche CNRS 7285, 40 avenue du Recteur Pineau, 86022 Poitiers Cedex, France

Beatriz A. Rodas-Junco Unidad de Bioquímica y Biología Molecular de Plantas, Centro de Investigación Científica de Yucatán, Calle 43#130 Col, Chuburná de Hidalgo, 97200 Mérida, Yucatán, Mexico

S. Sanchez-Rojo Programa Nacional de Papa, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP), Conjunto SEDAGRO, 52140 Metepec, México, Mexico

F. M. Shakirova Ufa Scientific Centre, Institute of Biochemistry and Genetics, Russian Academy of Sciences, pr. Oktyabrya 71, Ufa 450054, Russia

V. Sorokan Antonina Laboratory of the Biochemistry of Plant Immunity, Ufa Science Centre, Institute of Biochemistry and Genetics, Russian Academy of Sciences, pr. Oktyabrya 71, Ufa 450075, Russia

S. Supapvanich Faculty of Natural Resources and Agro-Industry, Kasetsart University, Chalermphrakiat Sakon Nakhon province campus, Sakon Nakhon province 47000, Thailand; Postharvest Technology Innovation Center, Commission on Higher Education, Bangkok 10400, Thailand

G. Szalai Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, Martonvásár, POB. 19, 2462, Hungary

K. Takeno Faculty of Science, Department of Biology, Niigata University, Ikarashi, Niigata 950-2181, Japan; Graduate School of Science and Technology, Niigata University, Ikarashi, Niigata 950-2181, Japan

T. Tounekti Unit of Biodiversity and Valorization of Bioresources in Arid Zones, Faculty of Sciences of Gabès, University of Gabès, Cité Erriadh, Zrig, 6072 Gabès, Tunisia

K. C. Wada Faculty of Agriculture, Department of Agricultural Chemistry, Niigata University, Ikarashi, Niigata 950-2181, Japan

Mohammad Yusuf Plant Physiology Section, Department of Botany, Aligarh Muslim University, Aligarh 202002, India

M. Zaman Ballance Agri-Nutrients Limited, Tauranga 12-503, New Zealand

About the Editors

Dr. Shamsul Hayat is an Associate Professor, in the Department of Botany, Aligarh Muslim University, Aligarh, India and presently working as Associate Professor in the Department of Botany and Microbiology, King Saud University, Riyadh, Saudi Arabia. He received his Ph.D. degree in Botany from Aligarh Muslim University, Aligarh, India. Before joining the Department as faculty, he has worked as Research Associate and Young Scientist in the same Department. His major areas of research are phytohormones and heavy metal stress in plants. Dr. Hayat has been awarded Prof. HiraLal Chakravorty Award by Indian Science Congress Association, Kolkata, India, Associate of National Academy of Agricultural Sciences, New Delhi, India, BOYSCAST fellow by Department of Science and Technology, Government of India, New Delhi and young scientist by Association of the Advancement of Science, Aligarh, India. He has been the Principal Investigator of the various projects sanctioned by different agencies and guided three students for the award of Ph.D. degree and two students for the award of M.Phil. degree. Dr. Hayat has published more than hundred research papers in leading journal of the world such as Environmental and Experimental Botany, Plant Physiology and Biochemistry, Environmental Pollution, Protoplasma, Plant Signalling and Behaviour and also published nine books published by Kluwer Academic, Springer, Wiley-VCH, Science Publisher and Narosa Publishing House. His work has been cited in various journals and at present about 1,700 citation has been noted.

Dr. Aqil Ahmad is the senior most Professor, in the Department of Botany, Aligarh Muslim University, Aligarh, India. He was conferred Ph.D. by Aligarh Muslim University, Aligarh in 1975. Dr. Ahmad worked as Post-Doctorate Research Fellow of Danish International Development Agency (DANIDA), in Plant Physiology at Royal Veterinary and Agricultural University. He has also worked at Department of Applied Sciences, Higher College of Technology, Muscat, Sultanate of Oman. He has been the Principal Investigator of various projects sanctioned by different Government agencies and guided six students for the award of Ph.D. degree. His current research area includes phytohormones and heavy metal stress. Dr. Ahmad has published more than hundred research papers and has edited a number of books, published by various leading publishers of India and Europe. His work has been cited in various leading journals.

Dr. Mohammed Nasser Alyemeni is a Professor, in the Department of Botany and Microbiology, King Saud University, Riyadh, Saudi Arabia. He has completed his M.Phil. from Reading University, UK and Ph.D. from Edinburgh University, UK in 1989. He has been the principal investigator of the various projects and guided four students for the award of Ph.D. degree. Dr. Alyemeni has published more than 50 research papers and also authored four books in the area of plant ecology in Arabic language. His current area of research is eco-physiology. He was the Regional Editor of Pakistan Journal of Biological Sciences. He has attended various National and International conferences held in different countries.