Crop Improvement Under Adverse Conditions

Narendra Tuteja • Sarvajeet Singh Gill
Editors

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Springer

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Professor Arturo Falaschi
(January 21, 1933–June 1, 2010)

Prof. Arturo Falaschi was born in Rome and graduated in Medicine in 1957 from Milan University. He undertook post doctoral trainings with J. Adler and Har Gobind Khorana (Nobel Prize in 1968 for deciphering the genetic code) in Wisconsin, USA (1961–1962), and later with Arthur Kornberg (Nobel Prize in 1959 for his studies on DNA replication) at Stanford (1962–1965). His main field of research was in the field of DNA replication and his contributions in this field are significantly important. His scientific work featured in the most prestigious international journals. Prof. Falaschi remains one of the few international researchers whose scientific activity is *documented throughout almost fifty years (from 1962 to 2010). Prof. Falaschi was responsible for the establishment of several research institutes and was a strong believer in the internationalization of science. Prof. Falaschi was very articulate and convinced several governments in the developed and the developing world to establish a 3-component International Centre for Genetic Engineering and Biotechnology (ICGEB), with one component in New Delhi, India, one in Trieste, Italy and one in Cape Town, South Africa. All these centres are devoted to research and training of young researchers from the developing world (www.icgeb.org). One of the focuses of ICGEB, New Delhi component is the development of crops resistant to various stresses. Prof. Falaschi was the mind and driving force in the founding and development of ICGEB, where he served as the Director General from 1989 to 2004. From 2004 to 2010, he worked as ICGEB Distinguished Scientist and Professor of Molecular Biology, Scuola Normale Superiore SNS, Pisa, Italy.*

This book is dedicated to the memory of Prof. Arturo Falaschi as a token of our appreciation and respect for him and his achievements.

Foreword

Plants are fundamental to life on Earth and they have been harnessed by humans for food, feed, fibre, fuel and fun. The need to increase crop production is becoming more urgent due to increasing population and diversion of crops to biofuels production. Furthermore, this needs to be done sustainably with reduced inputs and in the face of global environmental change. It is also notable that one-third of the world's food production is estimated to grow under irrigation—much of this irrigation is unsustainable, using water supplies that are overexploited and under threat from changing weather patterns resulting from global climate change. It is estimated that to meet the recent Declaration of the World Summit on Food Security target of 70 % more food by 2050, an average annual increase in production of 44 million metric tons per year is required, which is a 38 % increase over historical increases in production.

The gap between potential yield and actual yield is primarily due to the effects of abiotic stresses on crop production. It is therefore an imperative to improve our ability to maintain crop production in environments with suboptimal conditions, such as low water or nutrient supplies, or high salinity. This is, of course, required in addition to improving the efficiency of delivery of existing technologies into developing countries through improved education and outreach.

As such, the book edited by Dr. Narendra Tuteja and Dr. Sarvajeet Singh Gill provides a useful and timely compilation of up-to-date overviews of advances in the important area of plant sciences, "Crop Improvement Under Adverse Conditions". In this volume, a range of papers have been brought together which address both the technologies required to understand mechanisms of abiotic stress tolerance and the biological questions to which those technologies need to be applied. An understanding of the molecular and physiological aspects of plant function is provided in this book, and the emphasis on contributors from developing countries is very valuable—delivery of improved technologies and improved varieties of crops in such regions will have the greatest relative impact on global food production.

The editors and contributors are to be congratulated on their efforts, and readers are recommended to use this volume for a long time to come.

Mark Tester
Adelaide, Australia

Preface

Plant development and productivity are negatively regulated by various environmental stresses. Abiotic stress factors such as heat, cold, drought, salinity, wounding, heavy metals toxicity, excess light, flooding, high speed wind, nutrient loss, anaerobic conditions and radiations etc. represent key elements limiting agricultural productivity worldwide. The loss of productivity is triggered by a series of morphological, physiological, biochemical and molecular stress-induced changes. Such an unfavourable situation is in contrast with the increasing global food demand. World population is increasing at an alarming rate and is expected to reach more than nine billion by the end of 2050, whereas, plant productivity is being seriously limited by various abiotic stresses all over the world. Global climatic pattern is becoming more unpredictable with increased occurrence of drought, flood, storm, heat waves, and sea water intrusion. It has been estimated that abiotic stresses are the principal cause for decreasing the average yield of major crops by more than 50 %, which causes losses worth hundreds of millions of dollars each year. Therefore, to feed the world population maintaining crop productivity even under unfavourable environment is a major area of concern for all nations. Developing crop plants with ability to tolerate abiotic stresses is need of the day which demands modern novel strategies for thorough understanding of plant's response to abiotic stresses. Molecular breeding and genetic engineering have significantly contributed to expand the basic knowledge of the cellular mechanisms involved in stress response, suggesting new strategies to enhance stress tolerance.

In this book "Crop Improvement Under Adverse Conditions", we present a collection of 17 chapters written by 55 experts in the field of plant abiotic stress tolerance and crop improvement. It is a timely contribution to a topic that is of eminent importance. The chapters provide a state-of-the-art account of the information available on abiotic stress tolerance and crop improvement. In this book, we present the approaches for crop improvement under adverse environmental conditions. Chapter 1 deals with the research, development, commercialization, and adoption of drought- and stress-tolerant crops, where the factors affecting adoption of stress-tolerant crops by farmers are explored which includes complementary technologies, competing technologies, appeal to first-time users, distribution and timing of benefits to users, and social perceptions of the technology. Chapter 2 uncovers the impact of extreme events on salt-tolerant forest species of Andaman and Nicobar Islands. Chapter 3 deals with greenhouse gases emission from rice paddy ecosystem and their management. The plant development path of mitigating greenhouse gases (GHG) from agriculture cropping systems is not yet well established. Therefore aggressive research strategies and field validations are needed for establishing 'plant development' as a sustainable tool for GHG mitigation in agriculture sector. Chapter 4 covers remote sensing applications to infer yield of tea in a part of Sri Lanka. Chapter 5 deals with the polyamines contribution to the improvement of crop plants tolerance to abiotic stress, where, mechanism of action of polyamines to protect crop plants from challenging environmental conditions has been discussed. Chapter 6 discusses the overlapping horizons of salicylic acid in different stresses. In this chapter, the indigenous accumulation and overlapping roles of SA under different environmental and physiological conditions highlighting its recently updated roles and regulations in plants is discussed. Chapter 7 focuses on the effects of oxidative stress within the nuclear compartment where DNA becomes the main target of the highly toxic reactive oxygen species (ROS). Chapter 8 deals with a fast and reliable approach for crop improvement through in vitro haploid production. This chapter will act as a guide to prospective scientists working in the area of haploid production intended for crop improvement. Chapter 9 discusses the strategy for the production of abiotic stress-tolerant fertile transgenic plants using androgenesis and genetic transformation methods in cereal crops. Chapters 10 and 11 deal with the control and remedy of plant diseases through nanotechnology and the scope and potential of nanobiotechnology in crop improvement. The use of mutifunctionalised nanoparticles as plant transgenic vehicle for developing disease and stress resistant transgenic plants is discussed. Nanotechnological approaches on plants allow more efficient and sustainable food production by reducing the chances of disease and pest incidence in plants. In Chap. 11, thorough studies and reliable information regarding the effects of nanomaterials on plant physiology and crop improvement at the organism level are discussed. Chapter 12 deals with the role of nematode trapping fungi for crop improvement under adverse conditions. Chapter 13 uncovers the role of sugars as antioxidants in plants. This chapter discussed that soluble vacuolar carbohydrates (e.g. fructans) may participate in vacuolar antioxidant processes, intimately linked to the well-known cytosolic antioxidant processes under stress. All these insights might contribute to the development of superior, stress-tolerant crops. Chapter 14 deals with chromium toxicity and tolerance in crop plants, where, the mechanism of phytotoxicity and phytotolerance under Cr stress is discussed. Chapter 15 deals with boron toxicity and tolerance in crop plants, where, attempts to improve crop yields under boron-toxic soils is discussed. Chapter 16 deals with the approaches for stress resistance and arsenic toxicity in crop plants. Chapter 17 uncovers the mechanism of cadmium toxicity and tolerance in crop plants.

The editors and contributing authors hope that this book will include a practical update on our knowledge of "Crop Improvement Under Adverse Conditions" and lead to new discussions and efforts to the use of various tools for the improvement of crop plants under changing environment.

We are highly thankful to Dr. Ritu Gill, Centre for Biotechnology, MD University, Rohtak for her valuable help in formatting and incorporating editorial changes in the manuscripts. We would like to thank Prof. Mark Tester for writing the foreword and Springer Science+Business Media, LLC, New York, particularly Editor, Plant Sciences, Amna Ahmad and Developmental Editor/Project Manager, Daniel L.A. Dominguez and Andy Kwan, for their support and efforts. We have dedicated this book to Prof. Arturo Falaschi, the mind and driving force in the founding and development of ICGEB.

Narendra Tuteja
Sarvajeet Singh Gill

Contents

The Editors

Narendra Tuteja was born in 1955. Currently, Dr. Tuteja is working as a Senior Scientist in Plant Molecular Biology Group, International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi. Dr. Tuteja obtained his M.Sc., Ph.D and D.Sc. in Biochemistry from the Lucknow University in 1977, 1982 and 2008, respectively. He is fellow of the Academies of Sciences: FNASc. (2003), FNA (2007), FASc. (2009), FNESA (2009) and FTWAS (2012).

Dr. Tuteja has made major contributions in the field of plant DNA replication and abiotic stress signal transduction, especially in isolating novel DNA/RNA helicases and several components of calcium and G-proteins signaling pathways. Initially he made pioneer contributions in isolation and characterization of large number of helicases from human cells while he was at ICGEB Trieste and published several papers in high impact journals including EMBO J. and Nucleic Acids Research. From India he has cloned the first plant helicase (Plant J. 2000) and presented the first direct evidence for a novel role of a pea DNA helicase (PNAS, USA, 2005) in salinity stress tolerance and pea heterotrimeric G-proteins (Plant J. 2007) in salinity and heat stress tolerance. Dr. Tuteja has reported the first direct evidence in plant that PLC functions as an effector for Gα subunit of G-proteins. All the above work has received extensive coverage in many journals, including Nature Biotechnology, and bulletins all over the world. His group has also discovered novel substrate (pea CBL) for pea CIPK (FEBS J. 2006). He has already developed the salinity tolerant tobacco and rice plants without affecting yield. Recently, few new high salinity stress tolerant genes (e.g. Lectin receptor like kinase, Chlorophyll a/b binding protein and Ribosomal L30E) have been isolated from Pisum sativum and have been shown to confer high salinity stress tolerance in bacteria and plant (Glycoconjugate J. 2010; Plant Signal. Behav. 2010). Recently, very high salinity stress tolerant genes from fungus Piriformospora indica have been isolated and their functional validation in fungus and plants is in progress. Overall, Dr. Tuteja's research uncovers three new pathways to plant abiotic stress tolerance. His results are an important success and indicate the potential for improving crop production at sub-optimal conditions.

Sarvajeet Singh Gill was born on January 21st, 1979. Dr. Gill obtained his B.Sc. (1998) from Y.D. College, Kanpur University and M.Sc. (2001, Gold Medalist), M. Phil. (2003) and Ph.D (2009) from Aligarh Muslim University. Presently, Dr. Gill is working as Assistant Professor in Centre for Biotechnology, MD University, Rohtak, Haryana.

Dr. Gill's main area of research includes Genetic Engineering, Stress Physiology and Molecular Biology (Development of abiotic stress tolerant crop plants, the physiological, biochemical and molecular characterization of agronomically important plants under abiotic stress factors, involvement of mineral nutrients and other biotechnological approaches in the amelioration of abiotic stress effects in crop plants, use of a combination of genetic, biochemical, genomic and proteomic approaches to understand the responses of various components of antioxidant machinery to abiotic stress and stress signaling and stress tolerance in crop plants. Dr. Gill has several research papers, review articles and book chapters to his credit in the journals of national and international repute and in edited books. He has edited four books namely Sulfur assimilation and Abiotic Stress in Plants; Eutrophication: causes, consequences and control; Plant Responses to Abiotic Stress, Omics and Abiotic Stress Tolerance and Improving Crop Resistance to Abiotic Stress, published by Springer-Verlag (Germany), IK International, New Delhi, Bentham Science Publishers and Wiley-VCH, Verlag GmbH & Co. Weinheim, Germany, respectively. Dr. Gill is a regular reviewer of National and International journals and grants. He was awarded Junior Scientist of the year award by National Environmental Science Academy New Delhi in 2008. With Dr. Tuteja, Dr. Gill is working on heterotrimeric G proteins and plant DNA helicases to uncover the abiotic stress tolerance mechanism in rice. The transgenic plants overexpressing heterotrimeric G proteins and plant DNA helicases may be important for improving crop production at sub-optimal conditions.

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