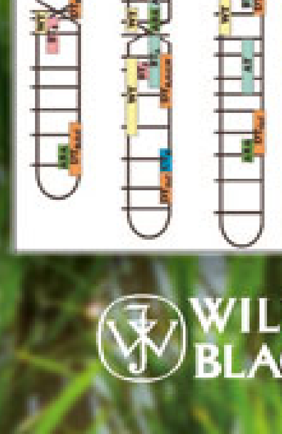
Improving Crop Productivity in Sustainable Agriculture

Edited by Narendra Tuteja,
Sarvajeet Singh Gill,
and Renu Tuteja





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Professor G.S. Khush (August 22, 1935)

Professor G.S. Khush was born in a small village in Punjab, India, and did B.Sc. in 1955 from Government Agricultural College (now Punjab Agricultural University), Ludhiana, and Ph.D. in 1960 from the University of California, Davis. After serving as an Assistant Geneticist at University of California, Davis, for 7 years, he joined International Rice Research Institute (IRRI), Los Banos, Philippines (1967), as a Plant Breeder. He was promoted as Head of Plant Breeding Department in 1972 and became Principal Plant Breeder and Head of Division of Plant Breeding, Genetics and Biochemistry (1986). Professor Khush is a world-renowned plant breeder who has made enormous contribution to the development of more than 300 high-yielding rice varieties that played significant role toward achieving “Green Revolution,” thereby boosting rice production. Professor

Khush provided excellent leadership for the global rice improvement program benefiting millions of resource-poor rice growers in the world. A semi-dwarf rice variety IR36 developed by him was one of the most widely grown rice varieties in the world during 1980s. IR64 developed during 1980s is the most widely planted rice variety in the world. In India, Professor Khush has been actively involved in the development of Plant Breeding and Agriculture Biotechnology. He has authored 3 books, edited 6 books, 40 review articles, 45 book chapters, and 160?research papers. His scientific work featured in the most prestigious international journals. Professor Khush received many awards and honors from various scientific bodies, such as Borlaug Award (1977), Japan Prize (1987), World Food Prize (1996), Rank Prize (1998), Wolf Prize (2000), and Padma Shri from the President of India. He received D.Sc. (hc) degrees from 10 universities, including Punjab Agricultural University, Jawahar Lal Nehru Agriculture University, De Montfort University, ?Cambridge University, and Ohio State University. He is elected to the Fellowship of Indian Academy of Sciences, Bangalore; National Academy of Sciences (India), Allahabad; National Academy of Agricultural Sciences, New Delhi; Indian National Science Academy (INSA), New Delhi; the Academy of Sciences for the Developing World; Chinese Academy of Sciences; Russian Academy of Agricultural Sciences; US National Academy of Sciences; and The Royal Society (London). At present, Professor Khush is serving as Adjunct Professor in University of California, Davis.

This book is dedicated to Prof. G.S. Khush, the undisputed Hero of Rice Revolution.

Foreword

Agriculture is now at a crossroad of conservation and sustainability along with the challenge of increasing productivity. Global agricultural land is limited; the same is true for the water availability and other natural resources. However, population is increasing, particularly in the developing countries. The vertical growth of crop productivity is the only way to meet the daunting task and ensure food security for ever-increasing population. I am glad to see this book addressing those issues and providing scientific know-how to solve some of the problems. I firmly believe that genetic potential of the crop productivity can be utilized and further improved through science and technology interventions.

Several chapters including (1) Climate Change and Food Security by Dr R.B. Singh, (2) Improving Crop Productivity under Changing Environment by Drs ?Dhillon, Gosal, and Kang, (3) Are Virus Always Villains? The Roles Plant Viruses May Play in Improving Plant Responses to Stress by Drs Wylie and Jones, (4) Risk Assessment of Abiotic Stress-Tolerant GM Crops by Drs Howles and Smith, (5) Rice: Genetic Engineering Approaches for Abiotic Stress Tolerance – Retrospects and Prospects by Dr Singh *et al.*, (6) Groundnut: Genetic Approaches to Enhance Adaptation of Groundnut (*Arachis hypogaea* L.) to Drought by Rao *et al.*, (7) Pulse Crops: Biotechnological Strategies to Enhance Abiotic Stress Tolerance by Drs Ganeshan, Gaur, and Chibar, and so on make focused discussions on the subject. All chapters are well written and create a scientific interest in the learners/readers and researchers.

Congratulations and my best compliments to editors of this book Drs N. Tuteja, Sarvajeet S. Gill, and R. Tuteja who performed an outstanding work in getting valuable contributions from some world experts on the relevant subject. I am sure the readers in the field of agriculture and particularly in abiotic stress management, biotechnology, and new genetics in plant breeding would find this book very useful. The publisher also deserves congratulations for publishing this useful book.

ICAR, New Delhi
April 11, 2012

Prof. Swapan K. Datta, FNAAS, FNASc
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Preface

The world's population is projected to hit ~9.2 billion in 2050. On the other hand, agricultural production is decreasing because of negative implications of global climate change. Therefore, it has become essential to increase the global agricultural production to feed the increasing population. Globally, a major loss in crop production is imposed by a suite of stresses, resulting in 30–60% yield reduction every year. Abiotic stress factors such as heat, cold, drought, salinity, wounding, heavy metal toxicity, excess light, floods, high-speed wind, nutrient loss, anaerobic conditions, radiation, and so on represent key elements affecting agricultural producti-vity worldwide. In an agriculturally important country, agriculture is the main driver of agrarian prosperity and comprehensive food and nutritional security. The?loss of productivity is triggered by a series of morphological, physiological, ?biochemical, and molecular stress-induced changes. Therefore, minimizing these losses is a major area of concern for the whole world.

Genetic engineering of abiotic stress-related genes is an important objective for increasing agricultural productivity. Plant adaptation to environmental stresses is?dependent on the activation of cascades of molecular networks involved in stress perception, signal transduction, and the expression of specific stress-related genes?and metabolites. Consequently, these genes that protect and maintain the function and structure of cellular components can enhance tolerance to stress. Genetic engineering of important genes and QTLs have now become valuable tools?in crop improvement for rapid precision breeding for specific purposes. Additionally, drip irrigation and fertigation, leaf color chart (LCC) for need-based application of nitrogen, sensor-based yield monitors, nitrogen sensors/green seekers, special-purpose vehicles with sensor-based input applicators, integrated nutrient management (INM) systems, integrated pest management (IPM) systems, integrated disease management (IDM) systems, site-specific management systems using remote sensing, GPS, and GIS, and Web-based decision support systems for controlling diseases and insect pests have been developed and are being commercialized for precision farming.

In this book "Improving Crop Productivity in Sustainable Agriculture," we present a collection of 19 chapters written by 55 experts in the field of crop improvement and abiotic stress tolerance. This volume is an up-to-date overview of current progress in improving crop quality and quantity using modern methods. Included literature in the form of various chapters provides a state-of-the-art account of the information available on crop improvement and abiotic stress tolerance for sustainable agriculture. In this book, we present the approaches for improving crop productivity in sustainable agriculture with a particular emphasis on genetic engineering; this text focuses on crop improvement under adverse conditions, paying special attention to such staple crops as rice, maize, and pulses. It includes an excellent mix of specific examples, such as the creation of nutritionally fortified rice and a discussion of the political and economic implications of genetically engineered food. The result is a must-have hands-on guide, ideally suited for the biotech and agro industries. This book best complements our previous title "Improving Crop Resistance to Abiotic Stress" (ISBN 978-3-527-32840-6, Volumes 1 and 2, Wiley-Blackwell, 2012).

For the convenience of readers, the whole book is divided into three major parts, namely, Part I: Climate Change and Abiotic Stress Factors; Part II: Methods to Improve Crop Productivity; and Part III: Species-Specific Case Studies. Further, Part III has been divided into three sections, namely, Section IIIA: Graminoids; Section IIIB: Leguminosae; and Section IIIC: Rosaceae. Part I covers four chapters. Chapter 1 deals with climate change and food security, where emphasis has been paid to food security and climate resilient agriculture. Chapter 2 uncovers the ways for improving crop productivity under changing environment. Chapter 3 deals with the approaches such as genetic engineering for acid soil tolerance in crop plants, whereas Chapter 4 focuses on the evaluation of tropospheric O_3 effects on global agriculture. Part II covers five chapters. Chapter 5 deals with "-omics" approaches for abiotic stress tolerance where emphasis has been paid to understand the ?importance of mitogen-activated protein kinases in abiotic stress tolerance in crop plants. Chapter 6 unravels the importance of plant growth promoting rhizobacteria for the amelioration of abiotic and biotic stresses for increasing crop productivity. Chapter 7 interestingly uncovers the importance of viruses in reducing damage from both biotic and abiotic stressors in crop plants. This chapter focuses on the new technologies that revealed that viruses are far more abundant and diverse than previously known and unexpected roles as symbionts and as sources of genetic raw material for evolution are informing a new appreciation of the roles plant viruses play in nature. Chapter 8 is on risk assessment of abiotic stress-tolerant GM crops. This chapter outlines the likely issues for consideration in risk assessment for the commercial release of a GM plant with a novel abiotic stress tolerance trait. Chapter 9 is on biofertilizers as potential candidate for crop improvement under stressed conditions. Part III deals with different crop plants under three sections. Section IIIA covers four chapters that deal with rice, pearl millet, and bamboo. In this ?section, Chapter 10 deals with the genetic engineering approaches for abiotic stress tolerance in rice – retrospects and prospects. Chapter 11 uncovers the genetic engineering approaches to enhance grain iron content in rice. The creation of nutritionally fortified rice can have a dramatic impact on human health because it is a major staple crop in the world. Chapter 12 deals with the genetic improvement for tolerance to abiotic stresses in pearl millet. Chapter 13 deals with the application of plant tissue culture techniques for genetic improvement of bamboo (*Dendrocalamus strictus* Nees). Section IIIB includes four chapters on groundnut, chickpea, grain legumes, and pulse crops. Chapter 14 deals with genetic approaches to enhance adaptation of groundnut (*Arachis hypogaea* L.) to drought stress. Chapter 15 discusses the strategies for crop improvement under changing environment conditions in chickpea. Chapter 16 deals with grain legumes, where biotechnological interventions in crop improvement for adverse environments have been discussed. Chapter 17 uncovers the biotechnological strategies to enhance abiotic stress tolerance in pulse crops. Section IIIC includes two chapters on *Fragaria* and rose. Chapter 18 deals with improving crop productivity and abiotic stress tolerance in cultivated *Fragaria* using "-omics" and systems biology approach. Chapter 19 discusses the strategies for improving crop productivity in rose. The editors and contributing authors hope that this book will add to our existing knowledge of improving crop productivity in sustainable agriculture that, in turn, may eventually open up new avenues for improving the stress tolerance in crop plants.

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. Swapan K. Datta, Deputy Director General (Crop Science), ICAR, New Delhi, for writing the foreword and Wiley-Blackwell, Germany, particularly Gregor Cicchetti, Senior Publishing Editor, Life Sciences, and Anne Chassin du Guerny for their professional

support and efforts in the layout. This book is dedicated to Professor G.S. Khush, the undisputed Hero of Rice Revolution.

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