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J.V. Patil *Editors*

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R. Madhusudhana
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ICAR-Indian Institute of Millets Research
Hyderabad, Telangana, India

P. Rajendrakumar
Biotechnology
ICAR-Indian Institute of Millets Research
Hyderabad, Telangana, India

J.V. Patil
Plant Breeding
ICAR-Indian Institute of Millets Research
Hyderabad, Telangana, India

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Preface

Sorghum is an important staple food crop in the semi-arid tropics of Asia and Africa. Sorghum is more nutritious than fine cereals and is the principal source of energy, protein, vitamins, and minerals for millions of the poorest people in these regions. It grows well in harsh environments with minimum inputs, where other crops yield poorly. The area of sorghum declined globally over the past few decades, primarily due to susceptibility to biotic and abiotic factors and marginal economics. In this scenario, genetic enhancement of grain and fodder yield is a major challenge to the sorghum breeders. The application of modern breeding approaches such as DNA marker-assisted breeding and transgenics will help in addressing this challenge more effectively. The use of DNA marker technology, in improving the breeding efficiency and designing superior cultivars with greater speed, precision, and value, has been well demonstrated in major crops.

DNA marker technology has undergone a major change during the last three decades. Significant advances in the sequencing technologies and bioinformatics resulted in quicker genome sequencing of a crop species at a relatively cheaper cost. This has brought about a revolution in marker discovery, high-throughput genotyping for QTL mapping, and gene discovery of economically important traits, making the application of marker-assisted selection (MAS) in breeding programmes more affordable. Pyramiding of desirable genes through MAS has now become a practice in several crop breeding programmes. The application of this technology for the mapping and dissection of complex traits will now permit wholly new approaches to the improvement of sorghum. Combining molecular marker and transgenic approaches with conventional breeding schemes can increase the overall selection gain and, therefore, the efficiency of a breeding programme.

Due to the advances in sequencing, genotyping, phenotyping, QTL mapping, genetic transformation, and tissue culture technologies, we are beginning to visualize the practical solutions for the genetic enhancement of sorghum through DNA marker-assisted breeding and transgenics. At this point, it is essential to look back and critically review the advancements made till now so that we can formulate suitable strategies for the future sorghum improvement programmes. To support this task, we have requested the contributors to present the information in a simple way so that it appeals to audiences from diverse backgrounds.

As a reference book, we are sure that this book on "Sorghum Molecular Breeding", a one stop information source for sorghum molecular breeding

research, will be of great help to students, teachers, managers, breeders, and biotechnologists, especially in sorghum, for planning future breeding strategies for the genetic improvement of sorghum, assisted by molecular breeding tools for achieving greater selection response and breeding efficiency. To accomplish this, we have attempted to cover important aspects of sorghum molecular breeding and transgenic research with emphasis on the marker development, application of DNA markers in genetic diversity, QTL mapping and heterosis breeding, bioinformatics resources, and transgenics.

This book is an account of comprehensive and critical review of up-to-date information featuring the latest approaches, technologies, resources, and practical progress in the area of marker-assisted breeding and transgenics in sorghum in the domain of genetic improvement. This book consists of 10 chapters accommodated in four sections, viz. Sorghum Introduction, Advances in DNA Marker Research, Advances in Genomics Research, and Advances in Transgenic Research.

Presenting an overview of sorghum molecular research, this book aims to expose the insights gained by several studies in sorghum molecular breeding involving genetics and breeding principles, molecular biology, bioinformatics, computational biology, and biotechnology. As a result, this book is intended to serve as a resource material to inter-disciplinary research groups comprising geneticists, breeders, biotechnologists, bioinformaticians, and students.

We are extremely grateful to all the learned contributors and sincerely thank them for their cooperation in compiling useful and updated information on different aspects of sorghum molecular breeding. We place on record our sincere thanks to Dr. S. Ayyappan, DG, ICAR, and Dr. SK Datta, DDG (Crop Science), ICAR, for their encouragements. We record our sincere gratitude to all the staff of IIMR who extended full support in several ways during the preparation of the book. We are confident that the book will be widely accepted by students, teachers, and researchers in the field of sorghum breeding in particular and plant breeding and life sciences in general.

Hyderabad, Telangana, India

R. Madhusudhana
P. Rajendrakumar
J.V. Patil

Contents

Contributors

D. Balakrishna Biotechnology, ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

B. Venkatesh Bhat Genetics & Cytogenetics, ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

K.N. Ganapathy Plant Breeding, ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

K. Hariprasanna Plant Breeding, ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

N. Sai Kishore GITAM Institute of Science, GITAM University, Visakhapatnam, Andhra Pradesh, India

P. Madhu ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

R. Madhusudhana Plant Breeding, ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

J.V. Patil Plant Breeding, ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

P. Rajendrakumar Biotechnology, ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

Sujay Rakshit Plant Breeding, ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

M. Swapna ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

K.B.R.S. Visarada Genetics & Cytogenetics, ICAR-Indian Institute of Millets Research, Hyderabad, Telangana, India

About the Editors

Dr. R. Madhusudhana, Principal Scientist (Plant Breeding), ICAR-IIMR

Dr. R. Madhusudhana is presently working as the principal scientist (Plant Breeding) at the ICAR-Indian Institute of Millets Research (formerly Directorate of Sorghum Research), Hyderabad, India. He graduated with a bachelor's degree in agricultural sciences and completed his master's in genetics and plant breeding from the University of Agricultural Sciences, Dharwad, India. He received his Ph.D. (Genetics) from the Indian Agricultural Research Institute (IARI), a premier institute of higher studies in agricultural sciences located in New Delhi, India. He was awarded with several gold medals for his academic achievements during his bachelor's, master's, and doctoral studies and was awarded I rank in Plant Breeding in Agricultural Research Services (ARS), ICAR, New Delhi. He was the recipient of DST-BOYSCAST fellowship and did his post-doc in the Institute of Grassland and Environmental Research, Aberystwyth, UK.

He joined ICAR-Indian Institute of Millets Research as a scientist in 1996 and then on successfully handled several national and international projects. He was involved in the development of two sorghum high yielding cultivars, CSH23 and CSV20, which were released for all India cultivation. Presently, he is working on molecular breeding of sorghum employing the tools of DNA markers for QTL (Quantitative Trait Loci) mapping of important traits and marker-assisted selection. He has trained several graduate students and guided six Ph.D. students and one M.Sc. student. He was also involved in the successful conduct of several training programs at IIMR (Indian Institute of Millets Research). He has more than 40 peer-reviewed foreign and national journal papers, four books and book chapters, and 15 other technical publications to his credit. He is a Life Member of the Indian Society of Genetics and Plant Breeding, New Delhi, India, and Society of Millets Research, Hyderabad, India.

Dr. P. Rajendrakumar, Senior Scientist (Biotechnology), ICAR-IIMR

Dr. P. Rajendrakumar, born in Puducherry, India, pursued his bachelor's degree in agriculture (1990–1994), master's (1995–1997), and doctoral degree in plant breeding and genetics (1997–2001) from Tamil Nadu Agricultural University, Coimbatore, India. He was a recipient of Dr. R. Appadurai Award, Dr. K. Ramaiah Award, and Dr. M.S. Swaminathan Award during his Ph.D. years. After completing his Ph.D. degree, he

worked as a research associate at the Centre for Cellular and Molecular Biology (2001–2004) and Directorate of Rice Research (2004–2008) in Hyderabad, India.

He joined the National Research Centre for Sorghum, Hyderabad, which was upgraded to Directorate of Sorghum Research and recently to ICAR-Indian Institute of Millets Research, as a senior scientist (Biotechnology) in 2008. He was the recipient of a three-year research project under the special grant, Rapid Grant for Young Investigators from the Department of Biotechnology, Government of India, in 2010. His research areas of interest include bioinformatics, marker-assisted breeding, and genomics. Current areas of research include the development of molecular markers through in silico analysis and application of genomics tools for understanding the molecular basis of grain yield heterosis and improvement of grain protein quality and iron and zinc content in sorghum. He has also organized a 21-day training on "Molecular Breeding Approaches for Genetic Enhancement of Millet Crops" as one of the course co-directors in 2014. He was awarded Junior Research Fellowship (JRF) by the Indian Council of Agricultural Research (ICAR), New Delhi, India, for pursuing his master's degree and Senior Research Fellowship (SRF) by the ASPEE Agricultural Research and Development Foundation, Mumbai, India, for pursuing his doctoral studies. He has guided one M.Sc. and one Ph.D. student. He is a Life Member of Indian Society of Plant Breeders, Coimbatore, India, and Society of Millets Research, Hyderabad, India. He has published 15 research papers in various peer-reviewed international journals and 10 research papers in national journals.

Dr. J.V. Patil, Director, ICAR-IIMR

Dr. J.V. Patil received his Ph.D. (Plant Breeding) from Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra, India. He rendered his teaching services and research activities at MPKV, Rahuri, as an associate professor (Plant Breeding) and professor (Genetics and Plant Breeding). He developed several high yielding cultivars of safflower (1), pulses (*Mungbean-1, French bean-1, Pigeonpea-2, Chickpea-5*), and sorghum (8). Dr. Patil joined as the director ICAR-Indian Institute of Millets Research, Hyderabad, in August 2010 and continues to render his services.

He advocated several innovative and economical farming techniques such as planting methods and in situ rainwater conservation in chickpea and post-rainy sorghum. Under his leadership, a successful model on value chain on sorghum is established, which has brought reputation not only to IIMR but also to ICAR in commercializing value-added sorghum technologies and reviving sorghum economy. He has 165 peer-reviewed foreign and national journal papers, 31 books and book chapters, and 90 other technical publications to his credit. He has guided as many as 16 Ph.D. and 16 M.Sc. students.

Dr. Patil is a recipient of "NAAS Fellowship Award," "Baliraja' Late Annasaheb Shinde Smruti Krishi Sanshodhan Gaurav Puraskar," and Maharashtra state's "Vasantrao Naik Krishi Puraskar" for outstanding research in the field of crop improvement and Maharashtra state's "Vasantrao Naik Award for Best Marathi Literature 2010 and 2012" and "Bharat Krishak Samaj Award 2012." He also received the team awards such as "CGIAR's Baudouin Award 2002" and "ICRISAT's Doreen Mashier Award 2002."

Part I

Sorghum: Introduction

Sorghum: Origin, Classification, Biology and Improvement

1

K. Hariprasanna and J.V. Patil

Contents

Abstract

Sorghum is a staple food crop for millions of poor people in the semi-arid tropics of Africa and Asia. It is one of the important dryland crops grown in marginal soils and a source of feed, fodder and biofuel apart from food. It is a short-day C_4 plant, and its easy adaptability to hot and dry agroecologies makes it a climate change-compliant crop. There are five basic races and ten intermediate races under cultivated taxa based on fundamental spikelet types. Sorghum is considered as an often cross-pollinated species, with outcrossing up to 6 % depending on the genotype and growing conditions. Extensive efforts in crop improvement have resulted in the development of a number of high-yielding cultivars with substantial yield increment over the years. The discovery and utilisation of the male sterility system have led to the successful commercial exploitation of heterosis. A number of biotic and abiotic yield-limiting factors, and changes in consumption pattern and demand have resulted in a steady decline in cultivated area over the years. Much progress has been achieved in the field of sorghum biotechnology, including genomics over the last two decades. Adoption of genomic tools and molecular breeding strategies can help in tailoring sorghum cultivars with desired traits to enhance the productivity under various limiting factors in the years to come.

K. Hariprasanna (✉) • J.V. Patil
Plant Breeding, ICAR-Indian Institute of Millets Research, Rajendranagar, Hyderabad, Telangana 500 030, India
e-mail: hari@millets.res.in

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