Biotechnologies of Crop Improvement, Volume 1

Satbir Singh Gosal • Shabir Hussain Wani
Editors

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Cellular Approaches

Springer

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ISBN 978-3-319-78282-9 ISBN 978-3-319-78283-6 (eBook)
https://doi.org/10.1007/978-3-319-78283-6

Library of Congress Control Number: 2018942727

Printed on acid-free paper

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

Edward C. Cocking graduated from the University of Bristol, UK, in Biological Chemistry followed by research doctorates on amino acid and protein synthesis in plants, plant cell biology and nitrogen metabolism, and was a Civil Service Commission research fellow in bacterial chemistry before being appointed to a lectureship in plant physiology at the University of Nottingham. His teaching and research at Nottingham identified the key importance of the study of the plant cell in relation to all aspects of plant and cell physiology and the interaction of plants with the environment and with microorganisms. His seminal publication in 1960 of an enzymatic method using cellulases to

degrade plant cell walls releasing protoplasts facilitated the use of these single, wall-free plant cells for a new era of plant cell physiology, biochemistry and molecular biology investigations. The uptake of plasmids, viruses and nitrogen-fixing bacteria by protoplasts, and the regeneration of whole fertile plants by cell and tissue culture methodology, coupled with the fusion of protoplasts to produce hybrids between sexually incompatible species, including those of rice, attracted grant support both nationally and internationally, including the Rockefeller Foundation. This enabled him to lead a multidisciplinary, international team, with predoctoral and postdoctoral researchers from India and China that played a major role in the Rockefeller Rice Biotechnology Programme, together with a UK Research Council Group that pioneered improvements in our knowledge of plant cell biology. He was Professor of Botany and Head of the Plant Genetic Manipulation Group from 1969 to 1997 and is now Director (Emeritus) of the Centre for Crop Nitrogen Fixation. His research record has been extensive and has been highlighted by a series of highly cited publications that have represented landmark developments in the plant sciences. His national and international leadership in plant biotechnology, plant cell and tissue culture, genetic manipulations and nitrogen fixation has resulted in his recognition nationally (Fellowship of the Royal Society), within Europe (Membership Academia Europaea, Hungarian Academy of Sciences) and internationally (World Innovation

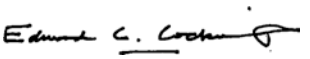
Foundation, Indian Academy of Agricultural Sciences). He has received a Life-Time Achievement Award from the University of Toledo for research on plant protoplasts and nitrogen fixation, and an Honorary D.Sc. from the University of Nottingham. In 1997, he organized a Discussion Meeting at the Rockefeller Foundation Bellagio Conference Centre on Biological Nitrogen Fixation, the Global Challenge and Future Needs, which enabled him to bring together international experts to formulate an action plan to develop nitrogen-fixing cereals and other non-legume crops; and in 2006, he took the first key step to achieve this objective by establishing nitrogen-fixing bacteria intracellularly in the root meristematic cells of crops, including cereals. This seminal publication has now resulted in numerous commercial international collaborations to establish symbiotic nitrogen fixation in crops for reduced inputs of synthetic nitrogen fertilizers, and for increased yields.

This book is dedicated to
Prof. Edward C. Cocking – father of protoplast technology.

Foreword

Biotechnology methods based on cell and protoplast culture hold significant promise for accelerated breeding and obtaining incremental improvement in crop cultivars. Plant tissue culture includes several specialized areas like micropropagation, meristem culture, micrografting, somatic embryogenesis, somaclonal variation, anther/pollen culture, embryo/ovule culture, protoplast culture/somatic hybridization, in vitro–assisted compression of breeding cycles and cryopreservation/in vitro freeze-storage of germplasm. These methods offer rich scope for creation, conservation and utilization of genetic variability for the improvement of field, fruit, vegetable, ornamental and forest plant species. Micropropagation of selected plant species is one of the best and most successful examples of the commercial application of tissue culture technology. Meristem culturing and in vitro grafting assist in developing disease-free plants. Somatic embryogenesis helps in cloning and genetic transformation resulting in transgenic crops. Production of haploids through bulbosum, anther/ pollen culture and embryo rescue from wide hybrids has been exploited for the production of haploids/doubled haploids for the early release of varieties. Embryo culture is the practical approach to obtain interspecific and intergeneric hybrids among otherwise difficult to cross parents. Somatic cell hybridization facilitates combining characteristics even from otherwise sexually incompatible species and the production of somatic hybrids/cybrids and organelle recombination not possible through conventional methods. In vitro freeze-storage and cryopreservation are imperative techniques for germplasm conservation especially of the vegetatively propagated plant species. Keeping all this in view, the editors have made strenuous efforts to include chapters covering the historical perspective and recent achievements in crop improvement using micropropagation, somatic embryogenesis, somaclonal variation, anther/pollen/embryo culture, in vitro freeze-storage and cryopreservation and somatic hybridization. Important crops such as rice, wheat, sugarcane, brassica, peanut, citrus, banana, apple, potato, eucalyptus, bamboo and medicinal and aromatic plants have been dealt with in detail. It is evident from the chapters that most of the cellular/protoplast techniques are now being routinely used in crop improvement programmes the world over. All chapters are well written by experts and will create much scientific interest not only in students but also in

teachers and researchers. I congratulate the editors of this book Dr. Satbir Singh Gosal and Dr. Shabir Hussain Wani for soliciting valuable contributions from a fine selection of experts on relevant aspects of these important crops; I am sure that this book will be highly rewarding for students, teachers and researchers in this area of cellular applications to crop improvement and biotechnology. The publisher particularly deserves congratulations for publishing this timely and useful book.



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Preface

Ever since the domestication of plants, breeders are making concerted efforts to improve crop yield and quality and developing resistance to various biotic and abiotic stresses. Using conventional breeding approaches, such as introduction, selection, hybridization, mutation, and polyploidy, an appreciable progress has been made and a series of improved cultivars have been developed, the world over. However, the breeding has been a difficult task in the presence of high level of heterozygosity, especially in the vegetatively propagated crops, cross-incompatibility, longer juvenile phase, seedlessness, complex polyploidy, lack of flowering, apomixes, polyembryony, and vegetative nature of propagation. In this regard, the innovative methods of cell and tissue culture hold significant promise to complement and supplement the conventional breeding methods for accelerated breeding. Spectacular advances in the area of plant cell, tissue, and protoplast culture offer a rich scope for creation, conservation, and utilization of genetic variability for the improvement of fields, fruits, vegetables, forest crops, and medicinal/aromatic plants. Plant breeders always look for new breeding tools to circumvent the recurring problems and to speed up the breeding process. The present book aims to describe the role of various in vitro techniques such as micropropagation, meristem-tip culture, micrografting, somatic embryogenesis, anther/microspore culture, somaclonal variation, embryo/ovule/ovary culture, protoplast culture and somatic hybridization, and cryopreservation/in vitro germplasm storage. Applications of these innovative methods for the improvement of crops such as rice, wheat, sugarcane, brassica, peanut, citrus, banana, apple, potato, eucalyptus, bamboo, and medicinal and aromatic plants have been dealt in detail in this volume. This book provides an authoritative review account of different aspects and progress in the field that has been made in the recent past. The book includes chapters prepared by specialists and subject experts on different aspects of tissue culture and crop improvement. The first chapter introduces various cell and tissue culture aspects in relation to crop improvement. Whereas six chapters deal exclusively with the micropropagation protocols for the mass production of super-elite planting material of sugarcane, banana, potato, eucalyptus, apple rootstocks, and bamboo. Two chapters on the fundamental facets of somatic embryogenesis in peanut and citrus have also

been included. The relevance of somaclonal variation and in vitro selection using stress factors has been well presented in three chapters. In vitro production of haploids/doubled haploids and their role in the accelerated breeding of world's two most important cereals, viz. rice and wheat, have been covered in two separate chapters. Likewise, a separate chapter dealing with in vitro–assisted compression of breeding cycles has been included for compressing the breeding cycle for the early release of crop varieties in the changing scenario of climate. Furthermore, the potential of cellular techniques for the improvement of medicinal and aromatic plants has been thoroughly discussed in the last chapter.

The book provides state-of-the-art information on cell and tissue culture tools to supplement and complement the conventional methods of crop improvement. We earnestly feel that this book will be highly useful for students, research scholars, and scientists working in the area of crop improvement and biotechnology at universities, research institutes, and R&Ds of agricultural MNCs for conducting research and various funding agencies for planning future strategies.

We are highly grateful to all learned contributors, each of who has attempted to update scientific information of their respective area and expertise and has kindly spared valuable time and knowledge.

We apologize wholeheartedly for any mistakes, omissions, or failure to acknowledge fully.

We thank our families (Dr. Satwant Kaur Gosal (wife of SSG); Sheikh Shazia and Muhammad Saad Wani (wife and son of SHW)) for their continuous support and encouragement throughout the completion of this book.

We highly appreciate the all-round cooperation and support of Springer International Publishing AG, Cham, for their careful and speedy publication of this book.

Ludhiana, Punjab, India — Satbir Singh Gosal
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Satbir Singh Gosal earned his B.Sc. (Med.) from PU, Chandigarh, India, and M.Sc. and Ph.D. (Plant breeding) from Punjab Agricultural University, Ludhiana, India. He was awarded fellowships by The Royal Society London and The Rockefeller Foundation (USA) for his Post-Doctoral Research at the University of Nottingham, England, and John Innes Centre Norwich, England. Dr Gosal has served Punjab Agricultural University in various capacities such as Professor Biotechnology, Director School of Agricultural Biotechnology, Additional Director Research, and Director of Research. He has also served FAO/IAEA, Vienna, Austria, and took tissue culture expert mission to Iraq during 1997. He has rigorous training on "Biosafety of GM crops" from Dan Forth Centre for Plant Science Research, St. Louis; APHIS, EPA (USDA), USTDA, Washington, DC, USA. He has been an Honorary Member of the Board of Assessors; Australian Research Council, Canberra; President Punjab Academy of Sciences; elected member (Fellow) of Plant Tissue Culture Association (India); and Fellow of Indian Society of Genetics and Plant Breeding. He is a recipient of Distinction Award by Society for the Promotion of Plant Science Research, Jaipur, India (2009); Fellow of Punjab Academy of Sciences; and Advisory member of several universities/institutes in the area of biotechnology. He served as a member of Review Committee on Genetic Manipulation (RCGM) for 3 years at Department of Biotechnology (DBT), Government of India, New Delhi, and is a member of panel of experts in area of Biotechnology for National Fund for Strategic Research of Indian Council of Agricultural Research, New Delhi. He has participated in more than 125 national/international conferences/meetings held in India, England, Scotland, Yugoslavia, Philippines, Indonesia, Thailand, The Netherlands, Malaysia, Singapore, Austria, Iraq, PR China, Australia, Mexico, Germany, and USA. He has guided more than 75 (M.Sc. and Ph.D.) students for theses research on various aspects of plant tissue culture and plant transformation. He executed more than 20 externally funded research projects funded by various national and international organizations such as Punjab State Government, ICAR, DBT, DAC NATP, FAO/IAEA, and The Rockefeller Foundation, USA. He has more than 200 research papers in refereed

journals of high repute, 135 research papers in conference proceedings, several TV/radio talks, and 30 book chapters. He has coauthored five laboratory manuals, one textbook, and two edited books.

Shabir Hussain Wani is an Assistant Professor cum Scientist, Plant Breeding and Genetics, at the Mountain Research Centre for Field Crops, Khudwani Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India, since May 2013 till date. He received his B.Sc. in Agriculture from Bhimrao Agricultural University, Agra, India, and M.Sc. and Ph.D. in Genetics and Plant Breeding from Central Agricultural University, Manipur, and Punjab Agricultural University, Ludhiana India respectively. His Ph.D. research fetched the first prize in North zone at national level competition in India. After obtaining his Ph.D., he worked as Research Associate in the Biotechnology Laboratory, ICAR-Central Institute of Temperate Horticulture, Rangreth Srinagar, India, for two years, up to October 2011. In November 2011, he joined the Krishi Vigyan Kendra (Farm Science Centre) as Programme Coordinator (i/c) at Senapati, Manipur, India. He teaches courses related to plant breeding, seed science and technology, and stress breeding. He has published more than 100 scientific papers/chapters in peer-reviewed journals, and books of international and national repute. He has served as Review Editor of Frontiers in Plant Sciences, Switzerland, from 2015 to 2017. He is an editor of *SKUAST Journal of Research* and *LS: An International Journal of Life Sciences*. He has also edited ten books on current topics in crop improvement published by reputed publishers including CRC press; Taylor and Francis Group, USA; and Springer. He is a Fellow of the Linnean Society of London and Society for Plant Research, India. He received various awards including Young Scientist Award (Agriculture) 2015, Young Scientist Award 2016, and Young Achiever Award 2016 by various prestigious scientific societies. He has also worked as visiting scientist in Department of Plant Soil and Microbial Sciences, Michigan State University, USA, for the year 2016–2017 under the Raman Post-Doctoral Research Fellowship programme sponsored by University Grants Commission, Government of India, New Delhi. He is a member of the Crop Science Society of America.