2ND EDITION

PLANT BREEDING

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WILEY Blackwell

Plant Breeding

2nd Edition of Introduction to Plant Breeding – revised and updated

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This edition first published 2014 © 2014 by John Wiley & Sons Ltd
First edition published 2008 by Blackwell Publishing Ltd..

Registered office: John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial offices: 9600 Garsington Road, Oxford, OX4 2DQ, UK
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Library of Congress Cataloging-in-Publication Data

Brown, Jack, 1955–
Plant breeding / Jack Brown, Peter D.S. Caligari, and Hugo A. Campos. – 2nd edition.
pages cm
"First edition published 2008 by Blackwell Publishing Ltd."
Includes bibliographical references and index.
ISBN 978-0-470-65829-1 (cloth) – ISBN 978-0-470-65830-7 (pbk.) 1. Plant breeding. I. Caligari, P. D. S. (Peter D. S.) II. Campos, Hugo A., 1968– III. Title.
SB123.B699 2014
631.5′2 – dc23

2014011407

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover images: Courtesy of Jack Brown

Set in 9.5/11.5pt Times Ten by Laserwords Private Limited, Chennai, India.

Printed in Singapore by C.O.S. Printers Pte Ltd

1 2014

Plant Breeding

Preface

This book has its basis in an earlier text entitled *An Introduction to Plant Breeding* by Jack Brown and Peter Caligari, which was published in 2008. So why have we produced this current book barely six years after the publication of the previous one? The answer is multiple, but the main driving force is the increasing need of humankind for affordable food, fibres and renewable fuels, which in great part needs to be satisfied through the creation of improved cultivars. Current and future demands from agriculture and an increasing contribution of private breeding organizations, in addition to the more traditional efforts of long-standing public breeding, has significantly improved our knowledge base and the techniques we now have available to improve the efficiency of developing genetically superior cultivars. The challenges facing today's plant breeders have never been more overwhelming, yet the prospects to contribute significantly to global food security and farmers' quality of life have never been more exciting and fulfilling. Let us elaborate further.

1. As per United Nations' figures for the year 2013, world population is projected to exceed 8 billion people by 2025, and 9.6 billion by the year 2050. Although most of the projected population growth will take place in developing countries, where over 8 billion will live by 2050, the most significant increase in population will occur in the least developed countries of the world. To place this in simple numbers, every single day over 200,000 additional children needing to be fed are added to the world population.
2. The rate of accumulation of both fundamental and applied genetic and plant breeding knowledge is ramping up faster than ever before. Drawing from initial research in animal breeding, genomic selection approaches in crop species are being vigorously studied, and their adoption and use into crop breeding programmes has already began. In addition, insights into the molecular basis of genetic variation in plants is being quickly advanced because of the drastic reduction in the cost of DNA sequencing, heavy borrowing from medical translational research; and an increasing awareness of the critical importance of phenotypes to establish better genetic marker–trait associations. This holds the promise to significantly improve the efficiency of selecting for a wide range of qualitative and quantitative gene traits in cultivar development.

   Furthermore, the traits developed through transgenic approaches are no longer constrained simply to insect or virus resistance or herbicide tolerance. New '*biotech traits*' addressing key global needs such as salt and drought tolerance, nitrogen and water use efficiency, or enhancing food quality are now being developed. Initial transgenic breeding efforts were directed towards improving some of the world's major crop species (i.e. maize, soybean, rice, cotton and canola) which are grown on the widest acreage. These techniques are now being applied to other staple crops, as demonstrated by the recent development of a virus-resistant common bean by public scientists based at EMBRAPA in Brazil.

3. Despite recent recognition of the need to increase public and private funding into cultivar development, over the last decades there has been a worrying decline in public funding for plant breeding-related research and to supporting international centres for germplasm development and crop improvement. In part, this has resulted in a serious reduction in the number of young people interested in devoting their professional careers to plant breeding, as well as the number of universities offering plant breeding courses or conducting relevant research in plant breeding for the next generation of plant breeders.

Although based on the earlier edition, this book has been completely reviewed, expanded and updated. We have also developed a companion website providing sections such as "Suggested answers" to the "Think Questions", "Further reading" and "Plant breeding teaching material" which can be used by lecturers and students alike.

We hope our book will appeal to undergraduate students of plant breeding, as well as providing valuable insight for graduate students, practicing plant breeders and those wishing to advance their understanding of plant breeding.

Our aim is to provide an integrated and updated view of the current scientific progress related to diverse plant breeding disciplines within the context of applied breeding programmes. By and large, plant breeders are integrators of multiple scientific disciplines, including genetics, biology, plant science, agronomy, food science and statistics, as well as having a keen appreciation and understanding of farmers' needs, both current and future. However, plant breeders also need to be aware of global trends affecting agriculture, such as the likely consequences of climate change for crop adaptation and performance.

We trust that this new book will encourage a new generation of students to pursue careers related to plant breeding. However, at the same time we hope it will assist a wider audience of agricultural students, agronomists, policy-makers and people with an interest in agriculture in gaining insight about the issues affecting plant breeding and its key role in improving the quality of life of people, and in securing sufficient food at the quality required at an affordable price.

In this latest book, the two original authors, Jack Brown and Peter Caligari, are joined by Hugo Campos, who adds further to the insights into the commercial aspects of plant breeding, along with his long experience in plant breeding.

All three of us would like to thank our families for their forbearance while we pursued the completion of this book, and a variety of mentors, colleagues and students who have all added to our knowledge and experience in a positive way.

About the Companion Website

This book is accompanied by a companion website:

www.wiley.com/go/Brown/Plantbreeding

The website includes:

- PDF version of the slides from Professor Caligari's Plant Breeding Course given at the Universidad de Talca, Chile
- Powerpoints of all figures from the book for downloading
- PDFs of all tables from the book for downloading
- Suggested answers to *Think Questions* from each chapter

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Introduction

1.1 Requirements of plant breeders

The aim of plant breeding is to develop genetically superior cultivars that are adapted to specific environmental conditions and suitable for economic production in a commercial cropping system. These new, and more productive cultivars, are increasingly necessary to fulfil humankind's escalating needs for food, fibre and fuels.

The basic concept of varietal development is rather simple and involves three distinct operations:

- produce or identify genetically diverse germplasm from which segregating breeding populations are developed;
- carry out selection procedures on phenotypes or genotypes from within this germplasm to identify superior genotypes with specific improved characteristics;
- stabilize and multiply these superior genotypes and release cultivars for commercial production.

The general philosophy underlying any breeding scheme is to maximize the probability of creating, and identifying, superior genotypes which will make successful new cultivars; in other words, genotypes that will contain all the desirable characteristics/traits necessary for use in a given production system, or at least offer a beneficial trade-off between key advantageous characteristics compared with undesirable ones.

Plant breeders can be categorized into two types. One group of plant breeders is employed within private companies, while the other group works in the public sector (e.g. government-funded research institutes or universities). Private sector and public sector breeders often have different approaches to the breeding process. Many of the differences that exist between public and private breeding programmes are related to the time available for variety release, types of cultivar developed, and priorities for traits in the selection process.

Plant breeders within the public sector are likely to have a number of responsibilities related to academic activities or extension services, in addition to those solely directed towards producing new varieties. Public sector breeders also play an additional, often unappreciated yet critical role: the attraction, training and development of a younger generation of men and women interested in plant breeding. As plant breeding is a combination of science and art, the personal component of training plant breeders at the graduate level is generally recognized as more relevant and significant than in most other areas of science.

Private sector plant breeders tend to have a more clearly defined goal: developing new cultivars and doing it as quickly as possible. In addition, many private breeding organizations are, or are associated with, biotechnology and/or agrochemical companies. As a result, varietal development may be designed to produce cultivars suitable for

Plant Breeding, Second Edition. Jack Brown, Peter D.S. Caligari and Hugo A. Campos.

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integration within a specific production system. In many countries, including the US, the ratio of private to public breeders has increased over time, particularly in those highest acreage crops such as maize, soybeans and canola, to mention just a few, as well as in crops with a high profit, such as tomato, pepper and lettuce, where private companies can gain greatest financial returns from seed or chemical sales.

Despite the apparently simple description of the breeding process given above, in reality plant breeding involves a multidisciplinary and long-term approach. Regardless of whether a breeding scheme is publicly or privately managed, a successful plant breeder will require knowledge in many (if not all) of the following subjects:

Evolution It is necessary to have knowledge of the origins and past progress in adaptation of crop species if additional advances are to continue into the future. When dealing with a crop species, a plant breeder benefits from knowledge of the timescale of events that have modelled the given crop. For example, the time of domestication, geographical area of origin and prior improvements are all important and will help in setting feasible future objectives. In the case of crops where hybridization systems are commercially available, such as canola and corn, the evolution from OP (open pollinated) to hybrid cultivars represents a landmark driving profound changes in ensuing breeding programmes.

Botany The raw material of any breeding scheme is the available germplasm (lines, genotypes, accessions, etc.) from which agronomically relevant variation can be exploited. The biological relationship that exists within a species and with other species will be a determining factor indicating germplasm variability and availability.

Biology Knowledge of plant biology is essential to create genetic variation and formulate a suitable breeding and selection scheme. Of particular interest are modes of reproduction, types of cultivar and breeding systems.

Genetics The creation of new cultivars requires manipulation of genotypes and genes. The understanding of genetic processes is therefore essential for success in plant breeding. Genetics is an ever-developing subject, but knowledge and understanding that is particularly useful will include single gene inheritance, population genetics, the expected frequencies of genotypes under selection, and the prediction of quantitative genetic parameters – all of which will underlie decisions on what strategy of selection will be most effective.

Pathology A major goal of plant breeding is to increase productivity and quality by selecting superior genotypes. A limiting factor in economic production is the impact of pests and diseases. Therefore developing cultivars that are resistant to detrimental pathogens has been a major contributor to most cost-effective production with reduced agrochemical inputs. Similarly, nematodes, insect pests and viruses can all have detrimental effects on yield and/or quality. Therefore plant breeders must also have knowledge of **phytopathology**, **nematology**, **entomology** and **virology**.

Weed science The response of a genotype to competition from weed populations will have an effect on the success of a new cultivar. Cultivars that have poor plant establishment, or lack subsequent competitive ability, are unlikely to be successful, particularly in systems where reduced, or no, herbicide applications are desirable, or their use is restricted. Similarly, in many cases genotypes respond differently, even to selective herbicides. Herbicide tolerance in new crops is looked upon favourably by many breeding groups, although cultivar tolerance to broad-spectrum herbicides can cause management difficulties in crop rotations. Herbicide tolerance brought about by traditional breeding as well as through recombinant DNA techniques has also driven changes in plant breeding approaches.

Food science Increasingly end-use quality is being identified as one of the major objectives of all crop-breeding schemes. As most crop species are grown for either human or animal consumption, knowledge of food nutrition and other related subjects is important.

Biometry Managing a plant-breeding scheme has aspects that are no different from organizing a series of large experiments over many locations and years. To maximize the probability of success it is necessary to use an appropriate experimental approach at all stages of the breeding scheme. Plant breeding is continually described as 'a numbers game'. In many cases this is true, and