Breeding Major Food Staples

Edited by
Manjit S. Kang and P.M. Priyadarshan
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Humans are guests of green plants on this planet. Green plants are a source of food, clothing, fuel, construction materials, and medicines. As ornamentals, they are aesthetically pleasing. Considering their importance for human survival and advancement of civilization, plants have been constantly improved since their domestication starting about 10,000 years ago. One has to compare modern varieties with their wild relatives to get an idea of the improvements that have been made. This conscious and unconscious selection has resulted in numerous primitive varieties, landraces, pure lines, and improved varieties of our crop plants. Plant breeders have utilized these genetic resources to develop highly productive modern varieties adapted to diverse growing environments.

The advancements in plant-breeding technology during the last century, based primarily on Mendelian genetics, have been employed for developing the productive crop varieties for feeding ever-increasing world population. The latest example of power of plant breeding is the green-revolution varieties of rice and wheat, which led to major increases in food grain production. During a 40-year period (1960–2000), world population doubled from 3.0 to 6.0 billion people, but food grain production increased threefold. The abundant food availability is the basis of unparalleled prosperity and political stability in Asia.

In spite of these advances in food grain production, 840 million people in the world still go to bed hungry everyday. World population is likely to increase from 6.5 billion now to 8 billion in 2025 and 9 to 10 billion in 2050. Moreover, as the standard of living improves, people start eating high-value foods, such as meat, milk, and eggs. This leads to increased demand for cereals as livestock feed. Considering this scenario, food production must double during the next 30–40 years. To meet this challenge, we need crop varieties with higher yield potential and greater yield stability.

The time-tested methods of classical plant breeding will be continuously employed, but modern advances in cellular and molecular biology and genomics are being increasingly utilized.

This book provides excellent reviews of present status of breeding food grain and tuber crops as well as bananas. These crops provide 60–65 of the calories consumed by the world population. Thus, their importance can hardly be overemphasized. The first two chapters are an authoritative review of classical and modern techniques of crop improvement. Worldwide, more than 2.5 billion people suffer from micronutrient deficiencies. During the past 10 years, importance of breeding food crops with dense micronutrients, such as iron, zinc, and vitamin A, has been emphasized and a new term “biofortification” has been coined. Therefore, the third chapter on biofortification is a useful addition. The fourth chapter deals with bioinformatics for managing voluminous data. None of the books on plant breeding has chapters
on bioinformatics. Thus, this chapter is another welcome addition.

I hope this volume will prove useful for students, teachers, and researchers working on crop improvement.

Gurdev S. Khush
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Preface

Population growth and food production are inextricably linked, food being one of the very basic needs of humans. In his 1798 publication “An Essay on the Principle of Population,” Thomas Robert Malthus wrote, “. . . the power of population is infinitely greater than the power in the earth to produce subsistence for man.” The Green Revolution of the 1960s/70s and the fact that Malthus’ dire predictions of population outrunning food supply by the middle of the 19th century failed reflects human ingenuity to develop and continually enhance scientific tools to increase food production. In addition, population growth has been slowed down through education and governmental policies.

Current world population is about 6.6 billion and increasing by the second, as indicated by the population ticker at http://www.irri.org/. The current population growth rate of about 1.2% or 77 million annually is substantially less than the 2% rate of the early 1970s. According to the U.S. Census Bureau, world population is expected to reach 9–10 billion by 2050. That food production would need to be doubled in the next 30 years and tripled in the next 50 years to feed people is an enormous challenge facing all involved in agriculture.

Poverty, hunger, food insecurity, and malnutrition remain serious problems around the world. An estimated 840 million people, which is 13% of the world population, remain chronically malnourished, with most of them living in less developed countries. In a speech on April 11, 2006 delivered to Biotechnology Industry Organization (www.bio.org), Chicago, Illinois, former U.S. President Bill Clinton eloquently highlighted this problem, “Keep in mind, half the world’s people live on less than $2.00 a day; a billion people live on less than $1.00 a day; a billion people go to bed hungry every night . . .”

Remarkable progress in production and productivity has been achieved during the past 50 years. Advances in agricultural technology, brought about by the re-discovery and application of Mendel’s laws of heredity, discovery of the structure of DNA, and science-based agricultural research during the 20th century, were the underpinnings of the progress.

In addition to various national agricultural research institutes and universities, international institutes have been at the forefront of solving the world food problem. The Consultative Group on International Agricultural Research (CGIAR), which has 15 centers around the world, has been charged with the mission of achieving sustainable food security and reducing poverty in developing countries. The CGIAR’s motto is “Nourishing the future through scientific excellence.”

Cereals have been and are expected to remain the most important calorie-providing staple food in the world. Rice, wheat, and maize are the leading cereals. Many CGIAR
research centers are devoted to reducing poverty and hunger in the world, and to ensuring secure access to food in Third World countries. For example, the mission of the International Rice Research Institute (IRRI) in the Philippines—a CGIAR center—is “To reduce poverty and hunger, improve the health of rice farmers and consumers and ensure that rice production is environmentally sustainable.” Similarly, the mission of the International Maize and Wheat Improvement Center (CIMMYT) in Mexico is “To use knowledge and technology to increase food security, improve the productivity and profitability of farming systems and sustain natural resources.” Other CGIAR centers also have similar missions.

The rapid pace at which the world population continues to increase dictates the continuing need to produce greater quantities of staple crops, such as rice, wheat, maize, potato, sweetpotato, cassava, soybean, barley, and banana to feed the people of the world. This publication, *Breeding Major Food Staples*, covers improving yields and quality of these crops through breeding, biofortification, and the use of molecular genetic tools, such as transformation (gene transfer), genome mapping, and bioinformatics. *Breeding Major Food Staples* brings together the state-of-the-art technical information through prominent experts in plant genetics and breeding, as well as bioinformatics. The book is divided into three sections: (a) general topics, which apply to all crops; (b) cereal crops; and (c) calorie- or carbohydrate-supplying root and tuber crops and bananas. There are two unique chapters in the book (section 1) that are generally not found in plant breeding textbooks: Biofortification and bioinformatics. Biofortification refers to the process of breeding food crops that are rich in bioavailable micronutrients, such as Fe, Zn, and vitamin A. Bioinformatics encompasses the fields of biology, computer science, and information technology.

Chapter 1, “Crop Breeding Methodologies: Classic and Modern,” discusses the various traditional and modern (molecular and genetic engineering) plant breeding methodologies. This chapter is not specific to any particular crop.


Chapter 3, “Biofortification: Breeding Micronutrient-Dense Crops,” is authored by two HarvestPlus scientists. HarvestPlus is an international, interdisciplinary research program, whose mission is to reduce micronutrient malnutrition by developing nutrient-dense staple foods through breeding.

Chapter 4 is focused on bioinformatics and plant genomics for staple crops improvement. Bioinformatics—a field yet to mature—plays an essential role in the sequencing and characterization of genomes as well as in trait analysis and optimization of breeding strategies.

Chapter 5, “Breeding Spring Bread Wheat for Irrigated and Rainfed Production Systems of the Developing World,” provides detailed breeding strategies to develop disease-resistant wheat and applications of molecular markers in wheat breeding.

Chapter 6, “Rice Breeding for Sustainable Production,” highlights, among other issues, the impact of rice breeding in the world, wide hybridization, use of molecular markers in rice breeding, and genetic transformation and transgenics.

Chapter 7, “Barley Breeding for Sustainable Production,” provides background information on the barley gene pool, types of barley, and diseases and pests of barley. It highlights important issues, such as doubled-haploid production, breeding for stresses, participatory breeding, and molecular breeding.

Chapter 8, “Corn Breeding in the Twenty-first Century,” traces the evolution of corn...
breeding in the USA into a vast hybrid-corn industry, while noting important technological developments, people who made it happen, and the social and political environment in which the corn industry flourished.

Chapter 9, “Soybean Breeding Achievements and Challenges,” provides a comprehensive picture of soybean breeding. It details first nutritional aspects of soybean, and then provides a discussion of soybean diseases and the modern breeding methodologies used in soybean improvement, e.g., genomics and genetic transformation.

Chapter 10, “Breeding Potato as a Major Staple Crop,” discusses domestication and evolution of the modern potato crop, genetic resources and transformation in potato, somaclonal variation, and resistances to biotic and abiotic stresses. This chapter also highlights molecular markers, quantitative trait loci (QTL) studies, gene cloning, and molecular marker-assisted introgression.

Chapter 11, “Breeding of Sweetpotato,” provides a thorough discussion of floral biology, breeding goals, nutritional quality, and breeding strategies used in sweetpotato improvement. Various biotechnological tools used in sweetpotato breeding, i.e., tissue culture and molecular breeding approaches, such as molecular-marker-assisted selection, are elaborated in this chapter.

Chapter 12, “Cassava Genetic Improvement,” describes the breeding objectives and schemes used in cassava improvement. In addition to a discussion of the hereditary aspects of important traits, molecular marker-use is described.

Chapter 13, “Banana Breeding,” thoroughly discusses Musa breeding strategies, resistance to diseases, insects, and nematodes, and biological control of pests. The accomplishments and strategies used in genetic transformation of Musa and the use of biotechnology as an adjunct to classical breeding in the genetic improvement of Musa are highlighted.

The monumental task of getting the book ready for printing would not have been possible without the cooperation and dedication of the authors. They deserve much appreciation and gratefulness. A word of thanks also goes to Mr. Justin Jeffryes and Ms. Erica Judisch of Blackwell Publishing, Ames, Iowa, without whose encouragement and support, the project could not have been completed.

We trust Breeding Major Food Staples will serve as not only a repository of research on various crops, but will also be useful for teachers and students of modern plant breeding. We hope this publication will stimulate new ideas and directions in research and help plant breeders meet the challenge of feeding almost eight billion people in the near term and possibly 10 billion people in the long term.

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