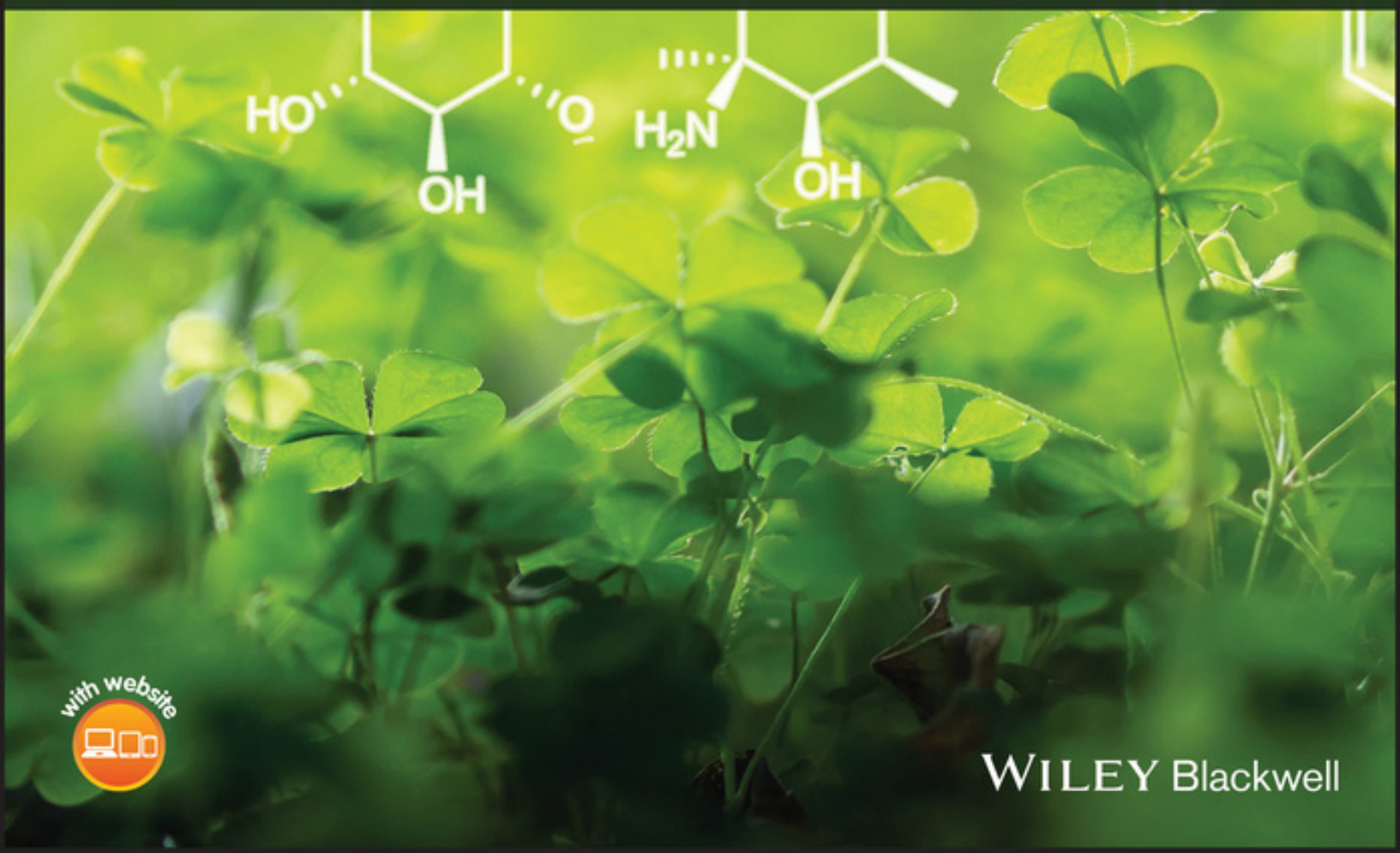




GEORGE ACQUAAH

# PRINCIPLES OF PLANT GENETICS AND BREEDING

THIRD EDITION



WILEY Blackwell



# **Principles of Plant Genetics and Breeding**

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# **Principles of Plant Genetics and Breeding**

**Third Edition**

**George Acquah**

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**WILEY** Blackwell

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To my wife, Theresa, with love and appreciation for uncommon character.





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# Preface

The third edition of *Plant Genetics and Breeding* represents a thoroughly overhauled version of its preceding edition, following recommendations and suggestions from users and reviewers. The major changes in the new edition include updated molecular genetics and breeding sections, and the addition of new box reading contributors. The book is copiously illustrated, as previously, to facilitate teaching and learning of the topics.

The book is organized into 14 sections. Section I is an overview and historical perspectives of plant breeding. Chapter 1 in this section provides an introduction to the field of plant breeding, describing its importance to society, while Chapter 2 provides historical perspectives, highlighting the contributions by researchers to knowledge in the field. The two chapters in Section II are devoted to discussing pertinent population and quantitative genetic concepts, to assist the reader in better understanding the practices of plant breeders.

Section III, reproductive systems, is organized into three chapters. Chapter 5 focuses on reproductive and genetic issues as they pertain to self-pollinated and cross-pollinated species. Chapter 6 is devoted to discussing the genetic issues associated with crossing plants to reorganize the genetic matrix, while Chapter 7 ends the section with a discussion of issues associated with clonal propagation. Section IV deals with germplasm for breeding. It is impossible to conduct plant breeding without the proper germplasm. Chapter 8 in this section focuses on variation and its genetic basis, while Chapter 9 focuses on domestication of plant species. The discussion includes the dependence of plant breeding on heritable variation. Finally, Chapter 10 speaks to the matter of plant genetic resources used in plant breeding. It includes a discussion of how germplasm is collected and managed for long term use by breeders.

Section V is devoted to discussing common breeding objectives pursued by plant breeders. The discussions include the genetic basis of those traits and the implication in their breeding. Chapter 11 focuses on breeding for increased yield and improving morphological traits that enhance crop productivity. In the ensuing Chapter 12, breeding for selected quality traits is the focus of discussion. A new Chapter 13 focuses on the role of the environment in breeding, with a discussion of climate change and its impact on breeding. Breeding for disease and pest resistance is a major breeding objective in most crops. This is the subject of Chapter 14, while Chapter 15 is devoted to issues pertaining to breeding for resistance or tolerance to selected abiotic factors such as salt tolerance.

The topics of Section VI focus on selection or breeding methods. In this section, breeding methods for autogamous species are the subject of Chapter 16, while Chapter 17 is devoted to breeding allogamous species. Chapter 18 concerns the selection methods used for breeding hybrid cultivars, while Chapter 19 is devoted to discussing the breeding methods used for clonally propagated species. The discussions in these chapters provide the advantages and disadvantages of each method, and include alternative approaches.

Molecular breeding is the subject of Section VII, which received significant overhaul. It focuses on technologies that are used to link genes to traits. The concept of markers and various commonly used molecular markers in plant breeding are discussed in detail in Chapter 20, including their advantages and disadvantages, as well the cost and ease of application in breeding. Chapter 21 is devoted to discussing the mapping of genes and the importance of such maps in plant breeding. Chapter 22 is new, and focuses on gene sequencing and the OMICs technologies. Section VIII discusses marker-assisted selection (MAS) as a method of facilitating plant breeding. Chapter 23 focuses on marker-assisted selection, while a new Chapter, 24, is devoted to genomic selection and related concepts. Section IX focuses on mutations and ploidy in plant breeding. Chapter 25 focuses on the use of mutagenesis for inducing variability for crop improvement. The discussions include the types of mutagens commonly used in crop improvement, and success of this approach to breeding. Many important crop species are polyploids. The methods used for improving polyploids are discussed in Chapter 26. Section X combines an old Chapter, 27, introducing the concept of genetic engineering, and a new one, Chapter 28, dealing with genome editing technologies, while Chapter 29 discusses additional new plant breeding technologies. Section XI is new, and deals with computer-aided applications in breeding, including bioinformatics and contemporary topics like big data in plant breeding in Chapter 30.

Section XII focuses on the variety release process, including discussion of  $G \times E$  interaction in Chapter 31, seed certification in Chapter 32, and regulatory issues in Chapter 33. Section XIII includes Chapter 34 that deals with ethical and other social issues associated with the use of modern technologies in breeding. The chapter ends the section with a discussion of the role international organizations in breeding. Section XIV, the final section in the book, is devoted to briefly discussing the breeding of selected crops.





# Acknowledgments

The author extends special gratitude to all old and new contributors to the industry highlights in the third edition. Several of these contributors were invited rather late to provide papers for inclusion in the new edition. Nonetheless, they came through with excellent papers. More importantly, the box readings are very detailed in the information they provide, and illustrate how the principles and concepts discussed in the main text are applied in addressing selected plant breeding problems.

I acknowledge, with appreciation, professors and industry professionals around the globe who have adopted this

textbook for their courses. I am grateful for the encouragement and commendations from professionals and students to produce this new edition, and especially to those who pointed out errors and typos, as well as those who suggested areas that needed updating.

My love and appreciation go to my dear wife, Dr. Theresa Acquah, and wonderful children, Parry, Kwasi, Bozuma, and Tina, who had to put up with all the time I took time away from them to focus on this great project. Finally, to my father, Dr. J.C. El-Shadai, I am grateful for your loving kindness, support, and guidance throughout this project.



# Industry highlights boxes

## Chapter 1

Training Game Changers in Plant Breeding at the West Africa Centre for Crop Improvement (WACCI) in Africa for Africa

Eric Danquah, Samule Offei, and Ronnie Coffman

## Chapter 2

No box

## Chapter 3

No box

## Chapter 4

No box

## Chapter 5

Introgression Breeding on Tomatoes for Resistance to Powdery Mildew

Yuling Bai

## Chapter 6

Maize and *Tripsacum*: Experiments in Intergeneric Hybridization and the Transfer of Apomixis: A Historical Review

Bryan Kindiger

## Chapter 7

Use of Comparative Molecular Markers and Plant Tissue Culture Techniques for Genetic Diversity Assessment and Rapid Production of *Musa* Species at Bowie State University

David Okeh Igwe, George Nkem Ude, and George Acquah

## Chapter 8

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## Chapter 9

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Richard Novy

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K. Hammer, F. Heuser, K. Khoshbakht, Y. Teklu

## Chapter 11

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W.T.B. Thomas

## Chapter 12

Development of High Pro-Vitamin A-Enriched Hybrid Maize Varieties in Ghana

Alexander Wireko Kena, Manfred Bondzie Ewool, Richard Akromah

## Chapter 13

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## Chapter 14

Breeding for Durable Resistance against Downy Mildew in Lettuce

Marieke Jeuken

## Chapter 15

Introgressomics for Adapting Crops to Climate Change

Mariola Plazas and Pietro Gramazio

## Chapter 16

Recurrent Selection with Soybean

Joseph Burton

## Chapter 17

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## Chapter 18

No box

## Chapter 19

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## Chapter 20

Molecular Marker Survey of Genetic Diversity in the Genus *Garcinia*

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Don L. Keim
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Yuling Bai
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- Supplementary Chapter 2  
Multivariate Methods: Applications in Plant Genetics, Breeding and Agronomy  
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