

SECOND EDITION

# Principles of Plant Genetics and Breeding



GEORGE ACQUAAH





# **Principles of Plant Genetics and Breeding**

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With figures and tables from the book.

# **Principles of Plant Genetics and Breeding**

**Second Edition**

**George Acquah**

*Bowie State University, Maryland, USA*

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## **Dedication**

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



# Contents

Preface, ix

Acknowledgements, xi

Industry highlights boxes, xiii

Industry highlights boxes: authors, xv

Section 1 Overview and historical perspectives, 1

1 Introduction, 3

2 History of plant breeding, 22

Section 2 Population and quantitative genetic principles, 41

3 Introduction to concepts of population genetics, 43

4 Introduction to quantitative genetics, 63

Section 3 Reproductive systems, 95

5 Introduction to reproduction and autogamy, 97

6 Allogamy, 121

7 Hybridization, 131

8 Clonal propagation and *in vitro* culture, 146

Section 4 Germplasm for breeding, 171

9 Variation: types, origin and scale, 173

10 Plant domestication, 185

11 Plant genetic resources, 199

Section 5 Breeding objectives, 227

12 Yield and morphological traits, 229

13 Quality traits, 246

14 Breeding for resistance to diseases and insect pests, 260

15 Breeding for resistance to abiotic stresses, 280

Section 6 Selection methods, 301

16 Breeding self-pollinated species, 303

17 Breeding cross-pollinated species, 337

18 Breeding hybrid cultivars, 355

19 Breeding clonally propagated species, 374

Section 7 Molecular breeding, 383

20 Molecular markers, 385

21 Mapping of genes, 402

22 Marker assisted selection, 424

23 Mutagenesis in plant breeding, 436

24 Polyploidy in plant breeding, 452

25 Molecular genetic modifications and genome-wide genetics, 470

Section 8 Marketing and societal issues in breeding, 489

26 Performance evaluation for crop cultivar release, 491

27 Seed certification and commercial seed release, 511

28 Regulatory and legal issues, 523

29 Value-driven concepts and social concerns, 543

30 International plant breeding efforts, 556

Section 9 Breeding selected crops, 575

31 Breeding wheat, 577

32 Breeding corn, 591

33 Breeding rice, 606

34 Breeding sorghum, 617

35 Breeding soybean, 629

36 Breeding peanut, 639

37 Breeding potato, 647

38 Breeding cotton, 657

39 Breeding tomato, 667

40 Breeding cucumber, 679

41 Breeding roses, 682

Supplementary chapters: review of genetic statistical principles, 689

1 Plant cellular organization and genetic structure: an overview, 691

2 Common statistical methods in plant breeding, 707

Glossary of terms, 726

Appendix 1: Conversion rates, 731

Index, 732

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# Preface

The second edition of *Principles of Plant Genetics and Breeding* represents a thoroughly overhauled version of the preceding edition, following recommendations and suggestions from users and reviewers. The major changes in the new edition include restructuring and reordering the chapters to follow more closely with how plant breeding is done in practice, and expanding the molecular genetics component. Also, the basic science information has been reduced. Two of the chapters in the first edition have been transferred to the back of the textbook as supplementary material, so it may be referred to by users only as needed. In this way, students and users who already have a background in genetics will not feel obligated to study those chapters before advancing to more plant breeding related topics. A feature of the first edition that is retained and expanded in the second edition is the inclusion of contributions on selected topics by industry professionals. The book is copiously illustrated to facilitate teaching and learning of the topics.

The book is organized into nine sections. Section I is an overview and historical perspective of plant breeding. Chapter 1 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, comprises four chapters. Chapter 5, autogamy, and Chapter 6, allogamy, focus on reproductive and genetic issues as they pertain to self-pollinated and cross-pollinated species, respectively. Chapter 7 is devoted to discussing the genetic issues associated with crossing plants to reorganize the genetic matrix, while Chapter 8 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 9 in this section focuses

on variation and its genetic basis, while Chapter 10 focuses on domestication of plant species. The discussion includes the dependence of plant breeding on heritable variation. Finally, Chapter 11 addresses 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 12 focuses on breeding for increased yield and improving morphological traits that enhance crop productivity. In the ensuing chapter, 13, breeding for selected quality traits is the focus of discussion. 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 is 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 the last chapter in the section, 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 the most overhaul. 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. Marker assisted selection (MAS) as a method of facilitating plant breeding is the subject of

Chapter 22. Chapter 23 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 the success of this approach to breeding. Many important crop species are polyploids. The methods used for improving polyploids are discussed in Chapter 24. The last chapter in this section, 25, addresses the subject of molecular genetic modifications, including the role of genetic engineering in plant improvement. Also, in this chapter, the contemporary subject of genome-wide genetics is introduced.

Section VIII is titled marketing and societal issues in plant breeding. In Chapter 26, the reader is exposed to the process of preparing a cultivar for release to farmers for use. Commercial seed producers ensure the quality of their products through the seed certification process, as described in Chapter 27. Plant breeders protect their products through securing legal protection, the subject of Chapter 28. The last two chapters, 29 and 30, end the section with discussions on social concerns that arise from the applications of biotechnological tools, and issues

confronting breeders on the international plant breeding scene.

The last section, IX, is devoted to discussion of the breeding of selected crops. This section includes discussions on the genetics of selected crop plants, germplasm used, and breeding methods used for their improvement. Professional highlights are provided for these chapters.

An effort has been made to organize this book such that the sequence of discussion of topics follows closely the sequence in conducting a plant breeding project. A plant breeding course, at the minimum, is usually an upper level course at the undergraduate level. It is assumed that a student taking a plant breeding course would have received prior instruction in the basic biology, including genetics, botany, and physiology. A review of basic genetic principles is helpful to better understanding the material in this book and a plant breeding course in general. Sometimes, some of this basic material is reviewed as appropriate. In addition, some of the underlying science is presented in the supplementary chapters of the book.

# Acknowledgements

The author extends special gratitude to Drs Herman van Eck, Rients Niks, Marieke Jeuken, Gerard van der Linden, Yuling Bai, Paul Arens, Luisa Trindade, Chris Maliepaard and Jaap van Tuyl of the academic staff of the Laboratory of Plant Breeding, Wageningen University and Research Center, in The Netherlands, for their outstanding contribution to this edition. Specifically, Drs Van Tuyl and Arens reviewed and edited Chapter 7 (Hybridization), while Dr van der Linden reviewed and edited Chapter 15 (Breeding for resistance to abiotic stress). Dr Jeuken wrote a boxed reading article on lettuce BILs, while Dr Bai contributed two articles, a supplement to Chapter 39 (Breeding tomatoes) as well as a paper on the introgression breeding of tomatoes as part of the industry highlights featured in the book. Chapter 13 (Breeding for quality) was reviewed by Dr Trindade. Dr Miliepaard deserves special mention for reviewing almost the entire first edition of the book and for making suggestions for accuracy and general improvement of the second edition.

Of the Wageningen team members, the author reserves his profound and deepest appreciation for the invaluable contributions of Dr Herman van Eck who made the initial contact with a proposal to assist with reorganizing the second edition, putting the team together and reviewing Chapter 23

(Mutagenesis in plant breeding) as well. Dr van Eck and Dr Niks collaborated with the author to reorder and restructure the chapters of the first edition to make the contents of the second edition flow more meaningfully. They also suggested additional chapters and topics for inclusion in the new edition. Dr van Eck provided the author with a collection of published literature and personal notes to assist with writing new chapters and updating others. Dr. Niks' additional role included critically reviewing and editing several chapters, including 5 (Autogamy), 6 (Allogamy), 7 (Hybridization), 8 (Clonal propagation) 10 (Domestication), 11 (Plant genetic resources) and, especially, chapter 14 (Breeding for disease resistance), which was overhauled according to his recommendations. The second edition is clearer and more accurate because of his thorough review and insightful critique of the chapters he reviewed.

Notwithstanding the tremendous contribution of the Wageningen team, the final content of the book remains entirely the responsibility of the author. The author also acknowledges with deep fondness the support of Dr Theresa Acquaah, his wife, for her moral support during the preparation of this edition. The final and ultimate appreciation is reserved for the author's mentor and source of inspiration, Dr J.C. El Shaddai.



# Industry highlights boxes

## Chapter 1

Normal Ernest Borlaug: The man and his passion  
George Acquaah

## Chapter 2

Barley breeding in the United Kingdom  
W.T.B. Thomas

## Chapter 3

Introgression breeding on tomatoes for resistance to powdery mildew  
Yuling Bai

## Chapter 4

Recurrent selection with soybean  
Joseph W. Burton

## Chapter 5

Haploids and doubled haploids: Their generation and application in plant breeding  
Sergey Chalyk

## Chapter 6

No box

## Chapter 7

No box

## Chapter 8

Maize and *Tripsacum*: Experiments in intergeneric hybridization and the transfer of apomixis – an historical review  
Bryan Kindiger

## Chapter 9

No box

## Chapter 10

The use of the wild potato species, *Solanum tuberosum*, in developing virus and insect resistant potato varieties  
Richard Novy

## Chapter 11

Plant genetic resources for breeding  
K. Hammer, F. Heuser, K. Khoshbakht, Y. Teklu, and M. Hammer-Spahillari

## Chapter 12

Bringing Roundup Ready<sup>®</sup> technology to wheat  
Sally Metz

## Chapter 13

QPM: Enhancing protein nutrition in sub-Saharan Africa  
Twumasi Afriyie

## Chapter 14

Breeding for durable resistance against an oomycete in lettuce  
Marieke Jeunke

## Chapter 15

Discovering genes for drought adaptation in sorghum  
Andrew Borrell, David Jordan, John Mullet, Patricia Klein, Robert Klein, Henry Nguyen, Darrell Rose-now, Graeme Hammer, and Bob Henzell

## Chapter 16

Utilizing a dihaploid-gamete selection strategy for tall fescue development  
Bryan Kindiger

## Chapter 17

No box

## Chapter 18

Pioneer Hi-Bred, a DuPont business – Bringing seed value to the grower  
Jerry Harrington

## Chapter 19

No box