Organic Crop Breeding
Edited by Edith T. Lammerts van Bueren and James R. Myers

Organic crop production utilizes different approaches and growing environments compared to conventionally raised crops to achieve production in growing systems that mimic natural ecosystems. These systems seek to employ fewer direct inputs and innovative agronomic methods to achieve this goal. This alternative approach has attracted great interest in this rapidly expanding method of crop production. Organic Crop Breeding brings together the latest research on the development of new varieties and cultivars best suited to thrive under organic production. It will also be of interest to those breeding in conventional systems who wish to adapt their breeding goals to sustainable low input agriculture.

Organic Crop Breeding will be a useful tool to helping meet the increasing global demand for organically produced grains, vegetables, and fruits. The book is divided into two sections that logically cover the topic from foundational principles to crop-specific examples of organic breeding efforts. The opening section looks at general topics related to organic crop breeding ranging from nutrient management to disease and pest resistance. The second section looks at the applications of these principles to economically important crops such as wheat, maize, rice, potatoes, legumes, and tomatoes.

Written by a global team of the leading experts in the field, Organic Crop Breeding is a field-defining reference that will be of both academic and practical use.

Editors:
Edith T. Lammerts van Bueren holds an endowed chair at Wageningen University as Professor of Organic Plant Breeding and senior researcher Organic Plant Breeding at the Louis Bolk Institute in the Netherlands.
James R. Myers is the Baggett-Frazier Professor of Vegetable Breeding and Genetics in the Department of Horticulture at Oregon State University.

Related Titles:
Breeding for Fruit Quality
Edited by Matthew A. Jenks and Penelope Bebeli
ISBN: 9780813810720

Plant Defense: Warding off attack by pathogens, herbivores and parasitic plants
Dale Walters
ISBN: 9781405175890

WILEY-BLACKWELL
Organic Crop Breeding
Dedication

We dedicate this book to all organic growers whose knowledge, vision, and wisdom has helped us to see the marvellous complexities of organic plant breeding through farmers’ eyes.
# Contents

**Contributors**

- Edith T. Lammerts van Bueren and James R. Myers

**Foreword**

- William F. Tracy

**Preface**

- Edith T. Lammerts van Bueren and James R. Myers

**Acknowledgments**

**Section 1 General Topics Related to Organic Plant Breeding**

- **Chapter 1 Organic Crop Breeding: Integrating Organic Agricultural Approaches and Traditional and Modern Plant Breeding Methods**
  - Edith T. Lammerts van Bueren and James R. Myers
  - Introduction 3
  - How Different Are Organic Farming Systems? 4
  - Consequences for Cultivar Requirements 5
  - From Cultivar Evaluation to Organic Seed Production and Plant Breeding Programs 6
  - The History of Organic Crop Breeding in Europe and the United States 8
  - Perspectives and Challenges for Breeding for Organic Agriculture 11
  - Conclusion 12
  - References 12

- **Chapter 2 Nutrient Management in Organic Farming and Consequences for Direct and Indirect Selection Strategies**
  - Monika Messmer, Isabell Hildermann, Kristian Thorup-Kristensen, and Zed Rengel
  - Introduction 15
  - Availability of Nutrients in Organic Farming 16
  - Roots: The Hidden Potential 17
  - Even Greater Complexity: Plant-Microbe-Soil Interactions 21
  - Importance of Selection Environments 27
  - Breeding Strategies 30
  - References 32
CONTENTS

Chapter 3 Pest and Disease Management in Organic Farming: Implications and Inspirations for Plant Breeding 39
Thomas F. Döring, Marco Pautasso, Martin S. Wolfe, and Maria R. Finckh

Introduction 39
Plant Protection in Organic Farming 42
Key Target Areas of Plant Breeding for Organic Plant Protection 46
Breeding Goals for Ecological Plant Protection 49
Plant Breeding Approaches Directly Targeting Pests or Diseases 50
Plant Breeding Approaches with Indirect Effects on Plant Health 53
Discussion and Conclusions 54
References 55

Chapter 4 Approaches to Breed for Improved Weed Suppression in Organically Grown Cereals 61
Steve P. Hoad, Nils-Øve Bertholdsson, Daniel Neuhoff, and Ulrich Köpke

Background 61
Crop Competitiveness Against Weeds 62
Crop Traits Involved in Weed Suppression 63
Selection of Traits and Their Evaluation in Plant Breeding Programs 64
Selection Strategies 68
Understanding Crop-Weed Interactions to Assist Plant Breeding 70
Concluding Remarks and Wider Perspectives 71
References 72

Chapter 5 Breeding for Genetically Diverse Populations: Variety Mixtures and Evolutionary Populations 77
Julie C. Dawson and Isabelle Goldringer

Introduction 77
Benefits of Genetic Diversity for Organic Agriculture 79
On-Farm Conservation of Useful Genetic Diversity 80
Breeding Strategies 81
Conclusion 94
References 94

Chapter 6 Centralized or Decentralized Breeding: The Potentials of Participatory Approaches for Low-Input and Organic Agriculture 99
Dominique Desclaux, Salvatore Ceccarelli, John Navazio, Micaela Coley, Gilles Trouche, Silvio Aguirre, Eva Weltzien, and Jacques Lançon

Introduction 99
Centralized and Decentralized Breeding: Definitions 100
What Can Be Decentralized in Breeding and Why? 100
Participatory Approaches 102
PPB: A Single Term Yielding Different Approaches 102
CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some Examples of PPB for Organic and Low Input Agriculture in Southern Countries</td>
<td>106</td>
</tr>
<tr>
<td>Some Examples of PPB for Organic and Low Input Agriculture in Northern Countries</td>
<td>113</td>
</tr>
<tr>
<td>General Conclusions and Limits of PPB Approaches in Organic Farming</td>
<td>119</td>
</tr>
<tr>
<td>References</td>
<td>120</td>
</tr>
<tr>
<td>Chapter 7 Values and Principles in Organic Farming and Consequences</td>
<td>125</td>
</tr>
<tr>
<td>for Breeding Approaches and Techniques</td>
<td></td>
</tr>
<tr>
<td>Klaus P. Wilbois, Brian Baker, Maaike Raaijmakers,</td>
<td></td>
</tr>
<tr>
<td>and Edith T. Lammerts van Bueren</td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>125</td>
</tr>
<tr>
<td>Arguments Against Genetic Engineering</td>
<td>126</td>
</tr>
<tr>
<td>Organic Basic Principles</td>
<td>127</td>
</tr>
<tr>
<td>Toward Organic Breeding</td>
<td>130</td>
</tr>
<tr>
<td>From Values to Criteria: Evaluation of Breeding Techniques</td>
<td>131</td>
</tr>
<tr>
<td>How to Deal with Varieties Bred with Non-compliant Techniques?</td>
<td>132</td>
</tr>
<tr>
<td>Toward Appropriate Standards to Promote Organic Plant Breeding</td>
<td>135</td>
</tr>
<tr>
<td>Discussion and Challenges for Organic Plant Breeding</td>
<td>136</td>
</tr>
<tr>
<td>References</td>
<td>136</td>
</tr>
<tr>
<td>Chapter 8 Plant Breeding, Variety Release, and Seed Commercialization:</td>
<td>139</td>
</tr>
<tr>
<td>Laws and Policies Applied to the Organic Sector</td>
<td></td>
</tr>
<tr>
<td>Véronique Chable, Niels Louwaars, Kristina Hubbard, Brian Baker,</td>
<td></td>
</tr>
<tr>
<td>and Riccardo Bocci</td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>139</td>
</tr>
<tr>
<td>The Developments of Plant Breeding and the Emergence of Seed Laws</td>
<td>139</td>
</tr>
<tr>
<td>Variety Registration</td>
<td>142</td>
</tr>
<tr>
<td>Seed Quality Control and Certification</td>
<td>144</td>
</tr>
<tr>
<td>Special Needs for Organic Agriculture</td>
<td>146</td>
</tr>
<tr>
<td>A Recent Development in Europe: Conservation Varieties</td>
<td>148</td>
</tr>
<tr>
<td>Intellectual Property Rights and Plant Breeding</td>
<td>151</td>
</tr>
<tr>
<td>Discussion</td>
<td>154</td>
</tr>
<tr>
<td>Conclusions</td>
<td>156</td>
</tr>
<tr>
<td>Notes</td>
<td>156</td>
</tr>
<tr>
<td>References</td>
<td>157</td>
</tr>
<tr>
<td>Section 2 Organic Plant Breeding in Specific Crops</td>
<td>161</td>
</tr>
<tr>
<td>Chapter 9 Wheat: Breeding for Organic Farming Systems</td>
<td>163</td>
</tr>
<tr>
<td>Matt Arterburn, Kevin Murphy, and Steve S. Jones</td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>163</td>
</tr>
<tr>
<td>Methods</td>
<td>163</td>
</tr>
<tr>
<td>Traits for Selection in Organic Breeding Programs</td>
<td>168</td>
</tr>
<tr>
<td>A Case Study for EPB: Lexi’s Project</td>
<td>170</td>
</tr>
</tbody>
</table>
A Case Study for Breeding within a Supply Chain Approach:
Peter Kunz and Sativa 171
Conclusion 171
References 172

Chapter 10  Maize: Breeding and Field Testing for Organic Farmers 175
Walter A. Goldstein, Walter Schmidt, Henriette Burger, Monika Messmer, Linda M. Pollak, Margaret E. Smith, Major M. Goodman, Frank J. Kutka, and Richard C. Pratt

Introduction 175
What Kind of Maize do Organic Farmers Want? 175
Are There Viable Alternatives to Single Cross Hybrids? 176
Testing and Using Alternative Hybrids 178
Are There Benefits for Breeding under Organic Conditions? 178
For Which Traits Is It Necessary to Test under Organic Conditions? 179
Choice of Parents for Breeding Programs 181
Breeding Programs 182
Future Directions 186
Notes 186
References 188

Chapter 11  Rice: Crop Breeding Using Farmer-Led Participatory Plant Breeding 191
Charito P. Medina

Introduction 191
MASIPAG and Participatory Rice Breeding 192
Beyond PPB: Farmer-Led Rice Breeding 193
The Breeding Process 194
Outcomes of the MASIPAG Program 198
Outlook 200
References 201

Chapter 12  Soybean: Breeding for Organic Farming Systems 203
Johann Vollmann and Michelle Menken

Introduction 203
Agronomic Characters 204
Seed Quality Features 208
Considerations on Breeding Methods 211
References 212

Chapter 13  Faba Bean: Breeding for Organic Farming Systems 215
Wolfgang Link and Lamiae Ghaouti

Purposes of Breeding and Growing Faba Bean 215
Genetic and Botanical Basics of Breeding Faba Bean 216
Methodological Considerations 218
Traits To Be Improved in Faba Bean Breeding 221
CONTENTS

Open Questions, Need for Action 223
References 224

Chapter 14 Potato: Perspectives to Breed for an Organic Crop Ideotype 227
Marjolein Tiemens-Hulscher, Edith T. Lammerts van Bueren, and Ronald C.B. Hutten

Introduction 227
Required Cultivar Characteristics 228
Introgression Breeding and Applied Techniques 232
Participatory Approach: An Example from the Netherlands 233
Outlook 234
References 234

Chapter 15 Tomato: Breeding for Improved Disease Resistance in Fresh Market and Home Garden Varieties 239
Bernd Horneburg and James R. Myers

Introduction 239
Botanical and Genetic Characteristics of Tomato 240
Rationale for Breeding Tomatoes within Organic Systems 240
Breeding Needs with Focus on Organic Production 243
Case Studies: Breeding for Late Blight Resistance in Europe and North America 245
Outlook 247
References 248

Chapter 16 Brassicas: Breeding Cole Crops for Organic Agriculture 251
James R. Myers, Laurie McKenzie, and Roeland E. Voorrips

Introduction 251
Rationale for Breeding within Organic Systems 251
Plant Biology 252
Traits Needed for Adaptation to Organic Production 253
Consideration of Breeding Methods 257
A Farmer Participatory Broccoli Breeding Program 258
Outlook 260
References 261

Chapter 17 Onions: Breeding Onions for Low-Input and Organic Agriculture 263
Olga E. Scholten and Thomas W. Kuyper

Introduction 263
Robust Onion Cultivars 264
Breeding for Improved Nutrient Acquisition 265
Mycorrhizal Symbiosis and Product Quality 269
Conclusion 270
References 271

Index 273
Contributors

Silvio Aguirre  CIPRES  Pueblo Nuevo, Nicaragua
Matt Arterburn  Department of Biology  Washburn University  Topeka, KS, USA
Brian Baker  The Organic Center, P.O. Box 20513, Boulder, CO 80308, USA; formerly with Alfred State College Sustainability Institute  Alfred, NY, USA
Nils-Øve Bertholdsson  Swedish University of Agricultural Sciences  Department of Plant Breeding and Biotechnology  Alnarp, Sweden
Riccardo Bocci  Italian Association for Organic Agriculture (AIAB)  Roma, Italy
Henriette Burger  KWS SAAT AG  Einbeck, Germany
Salvatore Ceccarelli  ICARDA  Aleppo, Syria
Véronique Chable  Institut National de la Recherche Agronomique (INRA)  Sciences for Action and Development (SAD-Paysage)  Rennes, France
Micaela Colley  Organic Seed Alliance  Port Townsend, WA, USA
Julie C. Dawson  Department of Plant Breeding and Genetics, Cornell University, Ithaca, NY 14853, USA; formerly with Institut National de la Recherche Agronomique (INRA)  Gif sur Yvette, France
Dominique Desclaux  INRA  Mauguio, France