

BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

# Achieving sustainable cultivation of cassava

Volume 2: Genetics, breeding, pests and diseases

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# Contents

Series list	x
Acknowledgements	xiv
Introduction	xv

## Part 1 Cassava genetic resources and breeding tools

1	Advances in understanding cassava growth and development	3
	<i>Virgilio Gavicho Uarrota, Deivid L. V. Stefen, Clovis Arruda de Souza and Cileide Maria Medeiros Coelho, University of the State of Santa Catarina (UDESC), Brazil; Rodolfo Moresco and Marcelo Maraschin, Federal University of Santa Catarina (UFSC), Brazil; Fernando David Sánchez-Mora, Technical University of Manabí (UTM), Ecuador; and Eduardo da Costa Nunes, Enilto de Oliveira Neubert and Luiz Augusto Martins Peruch, Santa Catarina State Agricultural Research and Rural Extension Agency (EPAGRI), Brazil</i>	
1	Introduction	3
2	Overview of cassava growth and development	5
3	Leaf development, canopy formation and photosynthesis	8
4	Root development	11
5	Carbon partitioning in cassava	12
6	Cassava response to environmental conditions: solar radiation and temperature	14
7	Cassava response to environmental conditions: water availability	17
8	Cassava response to environmental conditions: salinity, atmospheric CO <sub>2</sub> and other greenhouse gases	20
9	Post-harvest physiological deterioration	23
10	Summary and future trends	27
11	Where to look for further information	28
12	References	28
2	Conservation and distribution of cassava genetic resources	37
	<i>Michael Abberton, Badara Gueye, Tchamba Marimagne and Folarin Soyode, International Institute of Tropical Agriculture (IITA), Nigeria</i>	
1	Introduction	37
2	Origins and genetic diversity of cassava	38
3	<i>Ex situ</i> conservation of cassava genetic material	39
4	Field conservation of cassava genetic material	39
5	Core collections of cassava genetic material	40
6	<i>In vitro</i> conservation of cassava genetic material	41
7	Cryopreservation of cassava genetic material	42
8	Conservation of cassava genetic material as true seed	43
9	Data collection and management in genebanks	43
10	Germplasm distribution	44
11	<i>In situ</i> conservation of cassava genetic material	45
12	Molecular genetic studies of cassava diversity	45

13	Where to look for further information	46
14	Acknowledgements	46
15	References	46
3	Developing new cassava varieties: tools, techniques and strategies <i>Hernán Ceballos, Nelson Morante, Fernando Calle, Jorge Lenis and Sandra Salazar, International Center for Tropical Agriculture (CIAT), Colombia</i>	49
1	Introduction	49
2	Cassava breeding objectives	55
3	Pests and diseases of cassava	60
4	Evaluating and selecting cassava for breeding	61
5	Selection index in cassava breeding	66
6	Phenotypic correlations of cassava traits	67
7	Significance of breeding value	69
8	Quantitative genetics of complex traits in cassava	74
9	Future trends	77
10	Conclusion	80
11	Where to look for further information	81
12	References	82
4	Molecular approaches in cassava breeding <i>Luis Augusto Becerra Lopez-Lavalle, International Center for Tropical Agriculture (CIAT), Colombia</i>	91
1	Introduction	91
2	Genetic diversity	92
3	Marker-assisted selection (MAS)	93
4	Genome sequencing of cassava	95
5	Genetic engineering in cassava	96
6	References	97
5	Marker-assisted selection in cassava breeding <i>Ismail Y. Rabbi, International Institute of Tropical Agriculture (IITA), Nigeria</i>	101
1	Introduction	101
2	Molecular markers as genomic resources of cassava	103
3	Other cassava genomic resources	105
4	QTL mapping strategies	108
5	Genome-wide association mapping	111
6	Conclusion and future trends	111
7	Where to look for further information	112
8	References	112
6	Advances in genetic modification of cassava <i>P. Zhang, Q. Ma, M. Naconsie, X. Wu, W. Zhou, National Key Laboratory of Plant Molecular Genetics, CAS Center for Excellence in Molecular Plant Sciences, Chinese Academy of Sciences, China; and J. Yang, Shanghai Chenshan Plant Science Research Center, Shanghai Chenshan Botanical Garden, China</i>	117
1	Introduction	117
2	Transition from model cultivars to farmer-preferred cultivars	118
3	Tools of gene expression regulation	122

4	Production of virus-resistant cassava	123
5	Cassava biofortification for better nutrition	124
6	Starch modification of cassava for industrial applications	126
7	Improving storage, root production and post-harvest storage	127
8	Future trends and conclusion	130
9	Where to look for further information	131
10	Acknowledgements	131
11	References	131

## Part 2 Breeding improved cassava varieties

7	Breeding cassava for higher yield	139
	<i>Piya Kittipadukul, Pasajee Kongsil and Chalernpol Phumichai, Kasetsart University, Thailand; and Shelley H. Jansky, USDA-ARS Vegetable Crops Research Unit and University of Wisconsin-Madison, USA</i>	
1	Introduction	139
2	Genetic diversity for cassava breeding	140
3	Breeding programmes: key objectives and selection stages	143
4	Selection schemes for breeding	145
5	Breeding for higher yield: Thailand as a case study	149
6	Measuring the success of the Thai breeding programme	150
7	Relationships among Thai cassava varieties	152
8	Progress in the current Thai breeding programme	155
9	Adaptability of varieties	159
10	Combining ability in Thai varieties	162
11	Exploitation of homozygosity and heterosis in cassava	164
12	Conclusion: how to improve cassava breeding programmes	165
13	Where to look for further information	167
14	References	167
8	Breeding, delivery, use and benefits of bio-fortified cassava	171
	<i>Elizabeth Parkes and Olufemi Aina, International Institute of Tropical Agriculture (IITA), Nigeria</i>	
1	Introduction	171
2	The HarvestPlus breeding programme for pro-vitamin A cassava	173
3	Delivering pro-vitamin A cassava varieties to farmers: the HarvestPlus Programme in Nigeria	177
4	Encouraging use of pro-vitamin A cassava by consumers	181
5	Retention of carotenoids and bioavailability after processing	184
6	Quantification of carotenoid content in pro-vitamin A cassava varieties and food products	185
7	Conclusion and future trends	189
8	Appendix: Procedure for carotenoid determination using iCheck™ methodology	191
9	Where to look for further information	192
10	Acknowledgements	192
11	References	192

9	Breeding cassava to meet consumer preferences for product quality <i>Adebayo Abass, International Institute of Tropical Agriculture (IITA), Tanzania; Wasiu Awoyale, International Institute of Tropical Agriculture (IITA), Liberia and Kwara State University, Nigeria; and Lateef Sanni and Taofik Shittu, Federal University of Agriculture, Nigeria</i>	197
1	Introduction	197
2	Uses of cassava	198
3	Farmer, processor and end-user preferences	200
4	Target traits: nutritional and sensory properties	200
5	Target traits: processing properties	202
6	Target properties: products	205
7	Conclusions	206
8	References	206
<b>Part 3 Managing pests and diseases</b>		
10	Diseases affecting cassava <i>James Legg, International Institute of Tropical Agriculture (IITA), Tanzania; and Elizabeth Alvarez, International Center for Tropical Agriculture (CIAT), Colombia</i>	213
1	Introduction	213
2	Viral cassava diseases in Africa	214
3	Viral cassava diseases in Latin America and Asia	220
4	Bacterial blight, phytoplasmas and frogskin disease	224
5	Cassava fungal diseases: foliar	227
6	Cassava fungal diseases: root rots	230
7	Summary	232
8	Future trends in research	233
9	Where to look for further information	234
10	References	235
11	Integrated management of arthropod pests of cassava: the case of Southeast Asia <i>Ignazio Graziosi and Kris A.G. Wyckhuys, International Center for Tropical Agriculture (CIAT), Vietnam</i>	245
1	Introduction	245
2	Cassava pests in Southeast Asia	246
3	Guidelines for non-chemical pest management	254
4	Future trends and conclusion	259
5	Where to look for further information	260
6	Acknowledgements	260
7	References	260
12	Weed control in cassava cropping systems <i>S. Hauser and F. Ekeleme, International Institute of Tropical Agriculture (IITA), Nigeria</i>	271
1	Introduction	271
2	Effects of weeds on cassava cultivation: an overview	272
3	Cultural control measures: land management before planting	276

Contents

ix

4	Cultural control measures: planting and crop management	280
5	Mechanical weeding options	284
6	Chemical weed control	288
7	Herbicide-resistant cassava	292
8	Conclusion	292
9	Where to look for further information	293
10	References	293

Index

297

# Introduction

## 1 The roles, challenges and opportunities for cassava in development

For the last century agricultural scientists have embraced and met the challenges of providing technologies that gave farmers the capacity to stay ahead of the growing food demands from increasing populations. Hunger and malnutrition still exist -- and cause far too much misery and livelihood risk -- but UN statistics show clear progress in reducing food deficits at the global level. Agricultural science has ever more tools at its disposal, but at the same time an expanding panorama of expectations from its users. While the Green Revolution of the 1960s and beyond made landmark progress by focusing mainly on productivity of cereal grains under high input conditions, the world rightly demands more attention to environmental impact of agriculture (water quality, soil erosion, genetic resources), quality and nutrition of food, dwindling inputs for expanding productivity, and social justice issues such as equity and opportunity for women. Agricultural sciences are slowly adapting to these new realities, but not quickly enough, and with too few resources committed to success, especially in developing countries. This is the broader context within which we consider the cassava story as a key target for sustainable improvement.

Although cassava is little-known outside the tropics, globally it is the fourth most important calorie source after wheat, rice and maize. It is especially renowned as a crop that supports farmers in more marginal conditions and with poor access to inputs, due to its ability to yield well under low-fertility soils and with periodic drought where more sensitive crops would be devastated. Although it was domesticated from its wild ancestors in the Americas, over half of global production now comes from Africa where it has a leading role in food security. Cassava is largely an energy crop. Early in the growth cycle, beginning at about 2-3 months, some of the roots convert to starch storage organs. From a physiological standpoint, this is a mechanism to store energy through periods of stress, and for recovery when the stress is alleviated. In agriculture, farmers typically aim to minimize stress so that as much of the root starch as possible can be recovered for human use. Although cassava is often referred to as a *subsistence crop*, this is in fact only a small part of present-day production. There is a growing dichotomy between cassava as a low-input, low-yield crop of the poor, and cassava as a vibrant and highly flexible crop driven by industrial demand. Even in Africa where it is nearly entirely a crop of small farmers, mainly for human food, a large majority of production is marketed for off-farm use. In Asia, most of production is already for industrial uses, and with the exception of a few countries, especially Indonesia, India and the Philippines, human consumption is relatively low. Even in industrial markets, most of production is on small farms. Nonetheless, large-scale industrial systems are emerging around the globe, driven by robust demand for cassava products and by technologies that facilitate production and processing at scale. Some facets of cassava production are not easy to industrialize, i.e. to mechanize or implement at large scale, for several reasons. These constraints are gradually being overcome. Planting and harvesting can be mechanized. But there are still many aspects

of production that favor small farmer management, and cassava production is likely to be dominated by small farmers for decades to come. Just as the crop is grown primarily by poor farmers, consumers also tend to be from the lower income strata. For governments and development agencies who want to differentially benefit the poor, cassava is an ideal target for sustainable improvement.

## 2 Science progress and the needs for supporting cassava's future roles

Cassava's features, especially its minimal production in developed countries, have often meant that research investment has long been far less than for most important food crops. This situation was reversed to some degree when two International Agricultural Research Centers – the International Center for Tropical Agriculture (CIAT) in Cali, Colombia and the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria were founded in the late 1960s, and were mandated to work on cassava on a global scale (historically, CIAT in the Americas and Asia, and IITA in Africa). This investment motivated considerable parallel investment by national research programs around the world. Through the 1980s, most countries with significant cassava production had developed human and physical capital to improve the crop and the livelihoods of people who depended on it. However, by the 1990s, and especially in Latin America, many countries discontinued or severely cut funding to cassava research. A sort of *development fatigue* had set in for many traditional donors, and there was a rising belief that the private sector would take on much of the responsibility for crop improvement research. In other crops, and especially maize and soybeans, research was more and more taken on by the private sector, which was able to get a return on investment through the sale of technologies such as seed and chemicals. But cassava provided much less opportunity for profit from the private sector, and therefore lagged in technology development. By early into the 21st century, some of the key donor agencies for agricultural development began to recognize the need and the potential to invest in cassava, especially the Bill and Melinda Gates Foundation. In addition, the CGIAR -- parent organization of CIAT and IITA -- renewed its interest in cassava and recognized the synergies that could be achieved by joint work on key starchy, vegetatively propagated crops. Thus, in 2011, the Root, Tuber and Banana CGIAR Research Program (RTB-CRP) began operation, involving four CGIAR centers and five key crops (cassava, potato, sweet potato, bananas/plantains and yams). At about the same time, some of first major private sector investment in cassava research was initiated to develop amylose-free (*waxy*) cassava varieties in Thailand and Colombia.

While cassava still receives far less research funding in proportion to its value, compared to other major food crops, there has been key interest in recent years from donors, governments, and a limited number of private sector organizations to better fund cassava research. Cassava has been reasonably well-positioned in the molecular revolution, in terms of development of breeding techniques and information. However, the practical applications remain largely a future hope, and impact to date from breeding has been through more conventional approaches.

### 3 Bringing together the latest research and development information, and expected outcomes of this book

There is no recent comprehensive review of cassava research and development. With the explosion of information in general, and specifically about crop research, scientists have a difficult challenge to stay broadly informed about any crop, even one in which they may be specialized. These two volumes bring together global experts across the spectrum of cassava production and utilization topics, to distill and analyze information toward the broader context of achieving sustainable cassava cultivation. Apart from the broad chapter contents, the reader is provided extensive reference lists for further consultation and in-depth learning. This book will enable single-source consultation of a wide range of topics relevant to cassava R&D well into the future.

### 4 Section and chapter overviews

These two volumes present a comprehensive review of the history, the current strategies and the future potential to further transform cassava value chains toward sustainable systems. Each volume divides into three complementary sections.

**Volume 1: Part 1** describes the cassava plant and its uses. **Chapter 1** takes an ethnobiological journey through the crop's early history, informed especially by practices still carried out today in some of the crop's most traditional growing areas of South America's Amazon basin. **Chapter 2** describes the high diversity of food products from cassava, especially in Africa, where over 90% of cassava is destined for human food use. Many of the processes were brought from the crop's homeland in the America centuries ago, and expanded and modified to meet local needs. **Chapter 3** reviews the opposite end of the spectrum – cassava's diverse industrial uses, and especially starch. Much of SE Asia's production is destined for industrial uses, but Africa and Latin America are also advancing in these more sophisticated, value-added markets. **Chapter 4** shows the potential and some examples of the transformation of traditional products and markets into higher value markets in Africa, especially for high quality cassava flour (HQCF).

**Part 2** of Volume 1 begins within a broad overview of cassava production, processing and use across Asia, Africa and Latin America, **Chapter 5, 6 and 7**, respectively. Although the crop was domesticated in the Americas, only about 18% of current production comes from this region, and over half from Africa. These chapters compare and contrast the commonalities and differences among the regions, with lessons from each that can support sustainable development goals. **Chapter 8** draws on the regional overviews to highlight some of the global challenges and opportunities for sustainable cassava development, and the drivers of research and policy for setting priorities. Clearly there is no single strategy that applies globally, and every strategy fits into the context of an evolving social, economic, agronomic and environmental environment, among others. **Chapter 9** discusses the need to target and involve small-holder farmers in the development of cassava technologies, with case studies from Africa. **Chapter 10** presents the Global Cassava Partnership for the 21st Century (GCP21) as a global support partnership for cassava research and development. GCP21 is a not-for-profit international alliance of 45 organizations, aiming

to fill gaps in cassava R&D in order to unlock the potential of cassava for improving food security and income, especially for the poor.

**Part 3** of Volume 1 includes a comprehensive coverage of production practices for sustainable intensification of cassava production. **Chapter 11** describes the full range of production practices that growers should take into account to improve yields, profitability and sustainability – land preparation, plant populations, cropping systems, weed management, pest and disease management, and harvesting. The chapter draws heavily on experiences from Asia, but with relevance around the world. **Chapter 12** reviews the critical management of seed in cassava – normally through the vegetative reproduction through stem pieces. Currently nearly all seed is managed under informal systems, but this is slowly changing. Practices and systems developed in India inform the needs, challenges and experiences globally to develop improved seed systems. **Chapters 13, 14 and 15** give extensive coverage to best practices for managing cassava nutrition to achieve high and sustainable yields, through fertility management and soil conservation. As the demands increase for higher yield through sustainable practices, effective long-term soil fertility maintenance is a core strategy. The chapters draw especially on very extensive research and production experience in Asia and Latin America, where fertilizer use is far more common than in Africa. The chapters cover the relationship between soil fertility and crop productivity, how to diagnose nutritional needs and disorders, and best practices to achieve sustainable productivity through nutrient application. **Chapter 16** describes rotation and intercropping in cassava cultivation, especially common in Africa. There is a growing body of evidence on the sustainability and income advantages of diversified crop systems. Because of cassava's long period in the field, and its slow early growth, there is a wide range of alternative options for managing multiple crops that are complementary to cassava's growth and development. Finally, **Chapter 17** of Volume 1 reviews the principles of mechanization for all aspects of cassava production, which until now has been limited, especially in Africa. The chapter uses a case study of the Cassava Mechanization and Agro-Processing Project of the Africa Agricultural Technology Foundation to illustrate principles, challenges and opportunities for cassava mechanization.

**Volume 2** of *Achieving Sustainable Cassava Cultivation* covers genetic resources, breeding, and pests and diseases. **Part 1** focuses on genetic resources and breeding tools. **Chapter 1** reviews knowledge on cassava's unique growth and development features as a perennial crop managed as an annual, its vegetative propagation, and the fact that it has no phasic development as is the case for the grain and grain legume crops. This understanding is key to improving the crop through both management and breeding. **Chapter 2** describes the cassava's genetic resources, especially the *ex situ* collections managed by the International Agricultural Research Centers (CIAT and IITA), a fundamental resource for the crop's genetic improvement. **Chapter 3** delves into the genetic basis for cassava breeding, and provides novel and innovative strategies to move beyond the current plateau for improving cassava yield. In particular, the chapter describes in detail the rationale and the possible strategies to exploit heterosis and to make cassava breeding more efficient through the use of inbreeding. **Chapter 4** brings the reader up to date on the fast-moving repertoire of molecular knowledge that supports cassava breeding. While cassava lagged behind other major crops initially in the molecular revolution, it has been catching up fast in recent years and molecular techniques are poised to bring major benefits to the growers and consumers of this crop.

**Chapter 5** provides the technical background and describes specific molecular tools for making cassava breeding more efficient. The use of marker assisted selection (MAS) and genomic selection (GS) are covered in some detail. **Chapter 6** reviews the current status and the potential for improving cassava through genetic engineering, or genetic modification through targeting the insertion of genes directly into the crop's genome to achieve novel traits. In spite of rapid scientific advances, the regulatory environment limits impact at the field level while governments and the public assess and absorb the potential risks and benefits.

**Part 2** of Volume 2 looks at specific breeding goals for root yield and quality, and progress toward reaching them. **Chapter 7** uses a case study for cassava breeding programs in Thailand, which has had one of the world's most successful cassava improvement efforts through the collaboration of two local centers (The Department of Agriculture and Kasetsart University), with additional support from International Centers (CIAT) and the Thai cassava industry. The fact that breeding efforts were aimed exclusively at industrial markets allowed the Thai programs to focus on yield and starch content, and to gain valuable experience in breeding for these two traits. **Chapter 8** reviews a comprehensive program in West Africa to improve the nutritional content of cassava, for pro-vitamin A. The program supported by the HarvestPlus initiative demonstrates the many components of the value chain that need to be considered – from breeding through measuring nutritional impact at the household level. This case study is illustrative of the need for cassava improvement programs to be fully integrated with processors and consumers to develop successful products. **Chapter 9** reveals the importance and the complexity of breeding for the fine-tuned consumer preferences, especially in Africa where a plethora of different products and their regional variations present major challenges to breeders with regard to identifying priority traits and their prioritization for breeding. The chapter uses examples from Africa to sort through some of these complexities and guide breeders in their planning.

**Part 3** of Volume 2 covers pest and disease management in cassava, including weeds. These are areas that have received insufficient attention in the past, due to a widespread belief that cassava is a rugged crop that will produce reasonably well without any need to manage pests and diseases. However, as production practices have intensified, and especially as insects, mites and pathogens have moved with ease around the world, it is now well-understood that sustainable production is possible only with good management of these problems. **Chapter 10** describes the major diseases affecting cassava and their integrated management. It is noteworthy that two of Africa's most devastating problems – cassava mosaic disease and cassava brown streak disease – have not been found in the Americas where the crop and nearly all other of its pests and disease have co-evolved. Asia, once nearly free of serious disease problems, is recently experiencing new challenges, for example with witches broom disease and Sri Lankan cassava mosaic disease. **Chapter 11** reviews the arthropod pest complex of cassava and the importance of integrated pest management strategies. Because of cassava's long growth cycle, along with other factors, pesticide applications are usually not economically or ecologically sustainable. Cassava entomologists have a long success in biological control of major pests, especially the cassava mealybug, once one of Africa's most devastating pest problems and now brought under control in most regions through a parasitic wasp introduced from cassava's homeland in the Americas. **Chapter 12** discusses integrated weed management for cassava, with a focus on Africa. Currently, the vast majority of weed control is done

manually in Africa. However, the demands for more efficient and effective weed control are creating the need for research on new options, both mechanical and chemical, as well as refined crop management such as intercropping and supporting early-vigor and shading through fertilization, plant spacing and variety selection. In Africa, most weeding is done by women, and new options for better weed management can have broad gender implications for the continent.

# Index

- AFLP. *see* amplified fragment length polymorphisms (AFLP)
- Africa, viral cassava diseases in 214–220
- amplified fragment length polymorphisms (AFLP) 103
- arthropod cassava pests management
  - mealybugs
    - non-chemical 255–257
    - in Southeast Asia 247–250
  - mites
    - non-chemical 257–258
    - in Southeast Asia 250–252
  - overview 245–246
  - secondary pests 253–254
  - whiteflies
    - non-chemical 258–259
    - in Southeast Asia 253
- Asia, viral cassava diseases in
  - biology, symptoms and effects on yield 223
  - control 223–224
  - epidemiology 223
- atmospheric CO<sub>2</sub>, and cassava 21–22
- bioavailability, and carotenoids 184–185
- biofortification, of cassava
  - iron 125
  - vitamin A/carotenoids 125–126
  - vitamin B<sub>6</sub>, 126
  - zinc 124–125
- bio-fortified/pro-vitamin A cassava
  - consumption of 181–184
  - HarvestPlus breeding programme 173–177
    - in Nigeria 177–181
  - overview 171–173
  - quantification of carotenoid content 185–189
  - retention of carotenoids and bioavailability 184–185
- biomass management, and weed control 276–277
- breeding cassava
  - adaptability of varieties 159–162
  - advanced yield trials 65
  - combining ability in Thai varieties 162–164
  - exploitation of homozygosity and heterosis in 164–165
  - genetic diversity for 142–143
  - for higher yield
    - measuring success 150–152
    - overview 139–140
    - progress in 155–159
    - Thai commercial varieties 152–155
    - in Thailand 149–150
  - molecular approaches in 91–92
    - and genetic diversity 92–93
    - and genetic engineering 96–97
    - and genome sequencing 95–96
    - and marker-assisted selection (MAS) 93–95
  - objectives 143–145
    - cyanogenic glucosides (CG) 56–57
    - overview 55–56
    - root quality traits 57–58
    - shelf life of stored roots 57
    - starch, nutritional and peel characteristics in root 58–60
  - overview 197–198
  - preferences 200
  - preliminary yield trials 65
  - seed germination and seedling plant nurseries 62–64
  - selection index in 66–67
  - selection schemes for 145–149
  - significance of value 69–74
  - single row trials 64
  - uniform yield trials 65–66
  - use of checks 66
- CAD. *see* cassava anthracnose disease (CAD)
- canopy and leaf development 8–10
- carbon partitioning, and cassava 12–14
- carotenoids
  - and bioavailability 184–185
  - and pro-vitamin A cassava 185–189
  - vitamin A 125–126
- cassava. *see also* breeding cassava
  - fibre content 203–204
  - flowering biology of 54–55
  - growth and development
    - atmospheric CO<sub>2</sub>, 21–22
    - carbon partitioning 12–14
    - and greenhouse gases 21–22
    - leaf and canopy development 8–10
    - overview 3–7
    - photosynthesis 10–11
    - post-harvest physiological deterioration 23–27
    - root development 11–12
    - salinity 20–21
    - solar radiation 15–16

- temperature 16–17
- water availability 17–20
- nutritional properties 200–201
- overview 49–52
- pests and diseases of 60–61
- phenotypic correlations 67–69
- post-harvest physiological deterioration 204–205
- products 205–206
- quantitative genetics of 74–77
- sensory properties 202
- starch properties 203
- through stem cuttings 52–54
- uses of 198–199
- cassava anthracnose disease (CAD)
  - biology, symptoms and effects on yield 228
  - control 229
  - epidemiology 228
- cassava bacterial blight (CBB)
  - biology, symptoms and effects on yield 224
  - control 225
  - epidemiology 224
- cassava brown leaf spot (CBLs)
  - biology, symptoms and effects on yield 229
  - control 229–230
  - epidemiology 229
- cassava brown streak ipomoviruses
  - basic biology 218
  - symptoms and effects on yield 218–219
- cassava frogskin disease (CFSD)
  - biology, symptoms and effects on yield 225–226
  - control 227
  - epidemiology 226–227
- cassava fungal diseases
  - biology, symptoms and effects on yield
    - cassava anthracnose disease (CAD) 228
    - cassava brown leaf spot (CBLs) 229
    - Fusarium* spp 231
    - Phytophthora* spp 230
    - Rhizoctonia solani* 232
    - super-elongation disease (SED) 227–228
  - control
    - cassava anthracnose disease (CAD) 229
    - cassava brown leaf spot (CBLs) 229–230
    - Fusarium* spp 231–232
    - Phytophthora* spp 231
    - Rhizoctonia solani* 232
    - super-elongation disease (SED) 228
  - epidemiology
    - cassava anthracnose disease (CAD) 228
    - cassava brown leaf spot (CBLs) 229
- Fusarium* spp 231
- Phytophthora* spp 230–231
- Rhizoctonia solani* 232
  - super-elongation disease (SED) 228
- cassava genetic material
  - conservation of 43
  - core collections of 40–41
  - cryopreservation of 42–43
  - data collection and management in genebanks 43–44
  - ex situ* conservation of 39
  - field conservation of 39–40
  - germplasm distribution 44–45
  - molecular genetic studies of 45–46
  - origins and genetic diversity of 38
  - overview 37–38
  - in situ* conservation of 45
  - in vitro* conservation of 41–42
- cassava green mite (CGM) 94
- cassava haplotype map 106–107
- cassava mosaic begomoviruses (CMBs)
  - basic biology 214–215
  - control 217–218
  - epidemiology 215–217
  - symptoms and effects on yield 215
- cassava mosaic disease (CMD) 93–94
- cassava phytoplasmas 225–227
  - biology, symptoms and effects on yield 225–226
  - control 227
  - epidemiology 226–227
- CBB. *see* cassava bacterial blight (CBB)
- CBLs. *see* cassava brown leaf spot (CBLs)
- CFSD. *see* cassava frogskin disease (CFSD)
- CG. *see* cyanogenic glucosides (CG)
- CGM. *see* cassava green mite (CGM)
- chemical weed control
  - post-emergence herbicides 290–292
  - pre-emergence herbicides 288–290
- CMBs. *see* cassava mosaic begomoviruses (CMBs)
- CMD. *see* cassava mosaic disease (CMD)
- conservation, of cassava genetic material 43
- cover crop fallow 277–278
- cryopreservation 42–43
- cyanogenic glucosides (CG) 56–57
- ex situ* conservation, of cassava genetic material 39
- fertilizer, and weed control 282
- fibre content, in cassava 203–204

- field conservation, of cassava genetic material 39–40
- flowering biology, of cassava 54–55
- Fusarium* spp
  - biology, symptoms and effects on yield 231
  - control 231–232
  - epidemiology 231
- GBS. *see* genotyping-by-sequencing (GBS)
- GCA. *see* general combining ability (GCA)
- genebanks 43–44
- general combining ability (GCA) 163
- genetic diversity
  - and cassava breeding 92–93, 142–143
  - of cassava genetic material 38
- genetic engineering, and cassava breeding 96–97
- genetic modification, of cassava
  - and biofortification
    - iron 125
    - vitamin A/carotenoids 125–126
    - vitamin B<sub>6</sub>, 126
    - zinc 124–125
  - model cultivars to farmer-preferred cultivars 118–122
  - overview 117–118
  - root production and post-harvest storage 127–130
  - starch modification 126–127
  - tools of 122–123
  - and virus-resistant cassava 123–124
- genome sequencing
  - and cassava breeding 95–96
- genome-wide association studies (GWAS) 111
- genomic resources, and MAS
  - amplified fragment length polymorphisms (AFLP) 103
  - cassava haplotype map 106–107
  - genotyping-by-sequencing (GBS) 104–105
  - high-density genetic linkage maps 105–106
  - microsatellite or simple sequence repeats (SSR) 104
  - next-generation SNP markers 104–105
  - random amplification of polymorphic DNA (RAPD) 104
  - reference genome 106
  - restriction fragment length polymorphisms (RFLP) 103
  - single-nucleotide polymorphisms (SNPs) 104
- genotyping-by-sequencing (GBS) 104–105
- germplasm distribution 44–45
- greenhouse gases, and cassava 21–22
- GWAS. *see* genome-wide association studies (GWAS)
- hand tools, and weed control 284
- HarvestPlus breeding programme 173–177
  - in Nigeria 177–181
- herbicides
  - post-emergence 290–292
  - pre-emergence 288–290
  - resistant cassava 292
- heterosis, in cassava breeding 164–165
- high-density genetic linkage maps 105–106
- higher yield, cassava breeding for
  - measuring success 150–152
  - overview 139–140
  - progress in 155–159
  - Thai commercial varieties 152–155
  - in Thailand 149–150
- homozygosity, in cassava breeding 164–165
- in situ* conservation, of cassava genetic material 45
- intercropping
  - and weed control 281–282
- in vitro* conservation, of cassava genetic material 41–42
- iron 125
- labour requirements, and weed control 272–273
- land clearing, and weed control 276–277
- Latin America, viral cassava diseases in 220–223
  - biology, symptoms and effects on yield 221–222
  - control 222–223
  - epidemiology 222
  - overview 220–221
- leaf and canopy development 8–10
- manual hand tools 284
- marker-assisted selection (MAS)
  - advantages of 102
  - and cassava breeding 93–95
  - disadvantages of 102–103
  - genome-wide association studies (GWAS) 111
  - and genomic resources
    - amplified fragment length polymorphisms (AFLP) 103
    - cassava haplotype map 106–107
    - genotyping-by-sequencing (GBS) 104–105

- high-density genetic linkage
  - maps 105–106
- microsatellite or simple sequence repeats (SSR) 104
- next-generation SNP markers 104–105
- random amplification of polymorphic DNA (RAPD) 104
- reference genome 106
- restriction fragment length polymorphisms (RFLP) 103
- single-nucleotide polymorphisms (SNPs) 104
- overview 101–102
- QTL mapping 108–110
- MAS. *see* marker-assisted selection (MAS)
- mealybugs
  - non-chemical management of 255–257
  - in Southeast Asia 247–250
- mechanical weed control
  - manual hand tools 284
  - motorized tools 284–286
  - physical weed control options 287–288
  - tractor-drawn machines 286–287
- mites
  - non-chemical 257–258
  - in Southeast Asia 250–252
- molecular approaches, in cassava
  - breeding 91–92
  - and genetic diversity 92–93
  - and genetic engineering 96–97
  - and genome sequencing 95–96
  - and marker-assisted selection (MAS) 93–95
- molecular genetic studies 45–46
- motorized tools, for weed control 284–286
- near-infrared spectroscopy (NIRS) 187
- next-generation SNP markers 104–105
- Nigeria, HarvestPlus breeding programme in 177–181
- NIRS. *see* near-infrared spectroscopy (NIRS)
- non-chemical management
  - of mealybugs 255–257
  - mites 257–258
  - whiteflies 258–259
- nutrient sources, and weed control 282
- nutritional characteristics, in root 58–60
- nutritional properties 200–201
- peel characteristics, in root 58–60
- photosynthesis 10–11
- physical weed control options 287–288
- Phytophthora* spp
  - biology, symptoms and effects on yield 230
  - control 231
  - epidemiology 230–231
  - plant density, and weed control 280–281
  - planting patterns, and weed control 280–281
  - post-emergence herbicides 290–292
  - post-harvest physiological deterioration 23–27, 204–205
  - post-harvest storage, and genetic modification 127–130
  - pre-emergence herbicides 288–290
- random amplification of polymorphic DNA (RAPD) 104
- RAPD. *see* random amplification of polymorphic DNA (RAPD)
- reference genome 106
- restriction fragment length polymorphisms (RFLP) 103
- RFLP. *see* restriction fragment length polymorphisms (RFLP)
- Rhizoctonia solani*
  - biology, symptoms and effects on yield 232
  - control 232
  - epidemiology 232
  - root development, and cassava 11–12
  - root production, and genetic modification 127–130
  - root quality traits 57–58
- salinity, and cassava 20–21
- SCA. *see* specific combining ability (SCA)
- secondary pests management 253–254
- SED. *see* super-elongation disease (SED)
- seed germination 62–64
- seedling plant nurseries 62–64
- sensory properties 202
- shelf life of stored roots 57
- simple sequence repeats (SSR) 104
- single-nucleotide polymorphisms (SNPs) 104
- SNPs. *see* single-nucleotide polymorphisms (SNPs)
- solar radiation, and cassava 15–16
- Southeast Asia
  - mealybugs in 247–250
  - mites in 250–252
  - whiteflies in 253
- specific combining ability (SCA) 163
- SSR. *see* simple sequence repeats (SSR)
- starch characteristics, in root 58–60
- starch modification 126–127
- starch properties 203

- stem cuttings, cassava through 52–54
- super-elongation disease (SED)
  - biology, symptoms and effects on yield 227–228
  - control 228
  - epidemiology 228
- temperature, and cassava 16–17
- tillage regimes 278–280
- tractor-drawn machines 286–287
- uniform yield trials 65–66
- varietal choice, and weed control 282–283
- viral cassava diseases
  - in Africa 214–220
  - biology, symptoms and effects on yield
    - in Asia 223
    - cassava bacterial blight (CBB) 224
    - cassava brown streak
      - ipomoviruses 218–219
    - cassava frogskin disease (CFSD) 225–226
    - cassava mosaic begomoviruses (CMBs) 214–215
    - cassava phytoplasmas 225–226
    - in Latin America 221–222
  - control
    - in Asia 223–224
    - cassava bacterial blight (CBB) 225
    - cassava frogskin disease (CFSD) 227
    - cassava mosaic begomoviruses (CMBs) 217–218
    - cassava phytoplasmas 227
    - in Latin America 222–223
  - epidemiology
    - in Asia 223
    - cassava bacterial blight (CBB) 224
    - cassava frogskin disease (CFSD) 226–227
    - cassava mosaic begomoviruses (CMBs) 215–217
    - cassava phytoplasmas 226–227
    - in Latin America 222
    - overview 213–214
    - virus-resistant cassava 123–124
    - vitamin A/carotenoids 125–126
    - vitamin B6, 126
- water availability, and cassava 17–20
- weed control, in cassava
  - chemical
    - post-emergence herbicides 290–292
    - pre-emergence herbicides 288–290
  - cover crop fallow 277–278
  - critical phases of 273–276
  - fertilizer application and nutrient sources 282
  - herbicide-resistant cassava 292
  - intercropping 281–282
  - labour requirements 272–273
  - land clearing and biomass management 276–277
  - mechanical
    - manual hand tools 284
    - motorized tools 284–286
    - physical weed control options 287–288
    - tractor-drawn machines 286–287
  - overview 271–272
  - plant density and planting patterns 280–281
  - tillage regimes 278–280
  - varietal choice 282–283
  - and yield losses 273
- whiteflies
  - non-chemical 258–259
  - in Southeast Asia 253
- zinc 124–125