Achieving sustainable cultivation of bananas

Volume 1: Cultivation techniques

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## Contents

Series list x
Acknowledgements xv
Introduction xvi

### Part 1  Banana production and its challenges

1 The origin, domestication and dispersal of bananas 3  
   Hugo Volkaert, National Center for Genetic Engineering and Biotechnology, Thailand  
   1 Introduction 3  
   2 Origins: morphological and molecular evidence 4  
   3 The role of Musa balbisiana 9  
   4 Domestication and early cultivation of bananas 10  
   5 Archaeological evidence for early banana cultivation 11  
   6 Dispersal of bananas into Oceania 12  
   7 Dispersal of bananas into Africa 13  
   8 Dispersal of bananas in South and Southeast Asia 14  
   9 Conclusion 15  
  10 Where to look for further information 16  
  11 References 16

2 Understanding the banana industry: monoculture and beyond 21  
   Dan Koeppel, Independent Journalist and Researcher, USA  
   1 Introduction 21  
   2 Banana varieties and the Cavendish monoculture 22  
   3 The development of a banana monoculture 23  
   4 The dynamics of the banana monoculture 24  
   5 Post-war developments: business as usual? 25  
   6 The Cavendish era 27  
   7 Cavendish in crisis and a new paradigm 28  
   8 The hunt for new varieties 29  
   9 Future trends and conclusion 30  
  10 Where to look for further information 31

3 Banana cultivation in Africa 33  
   W. K. Tushemereinwe and J. Kubiriba, National Agricultural Research Laboratories, Uganda  
   1 Introduction 33  
   2 Cultivar composition and distribution 34  
   3 Production systems 35  
   4 Banana production in Uganda 39  
   5 Nutrient deficiencies 40  
   6 Moisture stress 41  
   7 Pests and diseases affecting bananas 41
8 Improving banana varieties for management of pests and diseases 50
9 Marketing as a constraint to banana production in Uganda 54
10 Future trends and conclusion 55
11 Where to look for further information 56
12 References 57

4 Challenges and opportunities for smallholders in banana value chains 65
William Tinzaara, Bioversity International, Uganda; Dietmar Stoian, Bioversity International, France; Walter Ocimati, Enoch Kikulwe and Gloria Otieno, Bioversity International, Uganda; and Guy Blomme, Bioversity International, Ethiopia
1 Introduction 65
2 Challenges along the value chain 67
3 Enabling an environment for addressing the challenges 79
4 Future trends 81
5 Conclusion 84
6 Where to look for further information 86
7 References 86

Part 2 Improving practices across the banana value chain

5 A functional approach to bunch formation in banana 93
D. W. Turner, School of Agriculture and Environment, The University of Western Australia, Australia; and D. J. Gibbs, Consultant, Australia
1 Introduction 93
2 Gross morphology and bunch form 94
3 Phases of development in banana 95
4 The floral phase: overview 97
5 Inflorescence 99
6 Formation of hands and fruit: independent but closely coordinated processes 102
7 Growth of the aerial true stem 108
8 Case study: photosynthate availability and bunch formation in banana 110
9 Conclusion 113
10 Where to look for further information 114
11 References 114

6 Banana plant propagation methods 117
Sharon D. Hamill, Department of Agriculture and Fisheries, Australia
1 Introduction 117
2 Background to banana evolution 118
3 Banana morphology and vegetative propagation 118
4 Bits and suckers 119
5 Propagation using conventional planting material 122
6 Banana tissue culture 124
7 Liquid culture systems 132
8 Banana off-types and how to reduce them 132
9 Future trends and conclusion 136
Contents

7  Conserving banana germplasm through field genebanks 143
   Mike Smith, Queensland Department of Agriculture and Fisheries, Australia
   1 Introduction 143
   2 Objectives of the field genebank 144
   3 Choosing the site 145
   4 Sourcing material 147
   5 Planting 149
   6 Crop management 150
   7 Quality control 151
   8 Dissemination of quality planting stock 152
   9 Case study 152
  10 Future trends and conclusion 155
  11 Where to look for further information 156
  12 Acknowledgements 157
  13 References 157

8  Good agricultural practices: an end point or a starting point for more sustainable banana production? 159
   Charles Staver, Bioversity International, France
   1 Introduction 159
   2 Why GAP in banana production? 161
   3 GAP-related certification schemes in banana production 163
   4 Is sustainable banana production being operationalized through GAP certification? 166
   5 Improving GAP for more sustainable banana production 172
   6 Scientific frontiers in bananas and implications for GAP 182
   7 Conclusion: mutual lessons between GAP certification and approaches to sustainable banana production 187
   8 Where to look for further information 189
   9 References 189

9  Challenges in cultivation of bananas in the subtropics 195
   Víctor Galán Saúco, Instituto Canario de Investigaciones Agrarias, Spain
   1 Introduction 195
   2 The influence of climate in banana production 196
   3 Main problems for banana cultivation in the subtropics 200
   4 Solving cultivation problems 200
   5 Other cultivation practices relevant to the subtropics 207
   6 Greenhouse banana cultivation 207
   7 Banana cultivars for the subtropics 216
   8 Plant protection 218
   9 Access to market 218
  10 Conclusion 219
  11 Where to look for further information 219
  12 References 220
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Nutrition and soil management in banana cultivation</td>
<td>Jetse J. Stoorvogel, Wageningen University, The Netherlands; and Rafael A. Segura, CORBANA S.A., Costa Rica</td>
<td>223</td>
</tr>
<tr>
<td>11</td>
<td>Harvesting and packaging of bananas</td>
<td>Juan José Aycart, Dole, Ecuador</td>
<td>235</td>
</tr>
<tr>
<td>12</td>
<td>Ripening systems for bananas</td>
<td>Frits Popma, Popma Fruit Expertise, The Netherlands</td>
<td>257</td>
</tr>
<tr>
<td>Part 3</td>
<td>Assessing and improving sustainability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Life cycle assessment and carbon footprint of banana cultivation</td>
<td>Louis Bockel, Laure-Sophie Schiettecatte and Orane Debrune, Food and Agriculture Organization (FAO), Italy</td>
<td>281</td>
</tr>
</tbody>
</table>
Introduction

Bananas are produced in over 135 tropical and subtropical countries and, according to the Food and Agriculture Organization (FAO), represented an estimated combined economic value of US $52 Billion in 2017. Each year more than 100 billion bananas are consumed globally and over 400 million people rely on bananas for their staple food or as a source of income. A large portion (85%) of the 113 million tons of bananas are consumed locally while the remaining 15% is exported, mainly to countries in temperate regions. Banana is the world’s most exported and valuable fruit and was, according to figures from the FAO, the sixth most valuable food crop after rice, maize, wheat, potato and soybean in 2016.

Despite their importance as a food crop, bananas are often considered an orphan crop when it comes to investment into making production more efficient and sustainable. Funds invested in research on bananas, in areas such as genetics, breeding, variety evaluation trials, physiology, pathology and entomology, have always been far less than the resources available to those researching major crops of comparable economic importance grown in temperate climes. Investment in interdisciplinary research involving environmental and social aspects of banana production is even further behind. Since no contemporary book exists on banana cultivation, we had no hesitation in agreeing to edit a three-volume book series on bananas. Volume 1 is focused on the cultivation of bananas, Volume 2 on genetics and breeding, and Volume 3 on banana diseases. Each volume stands on its own but together, we hope, the three books will provide a comprehensive review of all the key aspects of research into making cultivation more sustainable in the long term.

Bananas were among the first crops cultivated by man. Their wide utility as building and packing material, fibre for making rope and string, and cooked food in the form of starch from the corm and pseudostem, male flowers and the seeded bananas, preceded eating the seedless fruit we are familiar with today. Early farmers cultivated seeded bananas for these purposes in Asia, from which they identified seedless parthenocarpic plants which they subsequently propagated vegetatively. Movement of these plants by man in Southeast Asia also facilitated hybridisation between different Musa species, giving rise to novel interspecific hybrids. It is interesting to note that almost all varieties of banana we use today were selected by farmers in antiquity. Thousands of such varieties were selected in the past and brought into cultivation through vegetative propagation, giving rise to our current global suite of germplasm of seedless bananas. Since many seedless bananas are intra- and inter-specific hybrids which vary in ploidy level, they are expected to have high levels of heterozygosity which is maintained by man through ongoing vegetative propagation. Selections of Cavendish for example can, under ideal growing conditions and best agricultural practice, produce up to 80 tons of fruit per ha. Although modern plant breeding has played no role in generating the current varieties, the genetic yield potential of these early farmer selections compares very favourably to modern breeding efforts in other fruit crops.

On the one hand, continuous vegetative propagation and high levels of sterility in banana varieties locks in high genetic potential but, on the other, they also hamper significant genetic improvement of bananas. After discovering a new sterile hybrid in the wild, any advance in productivity solely relies on improving cultivation methods. Therefore the first book of the banana trilogy deals with development of sustainable cultivation techniques as outlined in more detail below.
Favourable clones, especially those of the Cavendish subgroup, which show very high levels of productivity, are widely used, giving rise to the contemporary global monoculture in banana production. The downside of the lack of genetic improvement and diversification is extreme genetic vulnerability, exacerbated by the need for uniformity in the transport and ripening process. This lack of diversity can only be overcome through much wider utilisation of available germplasm and by generating new varieties that meet consumer demands and sustainability targets. Genetics is the key to achieve that goal and therefore the second book is focussed on the current state of knowledge with regard to genetic improvement and diversification of bananas.

The spread of bananas around the globe over the last century has instigated the spread of a range of important plant diseases such as yellow and black Sigatoka, Fusarium wilt and banana bunchy top virus. Simultaneously, new diseases were encountered such as Xanthomonas wilt in Africa and Moko disease in Latin America. Increases in travel and trade have enabled pathogens which originated in different parts of the world to spread rapidly to new areas and the lack of resistance against some of these pathogens has caused some of the most damaging plant disease epidemics. Therefore the third book in the series focuses on the latest research into the myriad of pathogens affecting bananas and how to improve disease management in a sustainable manner.

Our hope is that the contributions of leading experts will combine into an integrative state-of-art banana trilogy that provides a springboard for a new generation of banana stakeholders to develop a sustainable banana sector.

As noted, Volume 1 consists of three parts which review key research on improving the efficiency and sustainability of global banana production:

- Part 1 reviews current challenges in banana production
- Part 2 surveys ways of improving cultivation practice across the value chain, from propagation to harvesting and ripening
- Part 3 assesses ways of measuring and improving the environmental impact of banana cultivation

Each of these three parts is discussed in more detail below.

## Part 1  Banana production and its challenges

The themes of chapters in the first part of the volume range from the origin, domestication, dispersal and production of bananas to the role of monoculture in banana cultivation, and challenges and opportunities for smallholders in banana value chains. Chapter 1 details the search for the origins of edible bananas, which probably began soon after European explorers returned home with stories of a fruit they had discovered in Africa. Currently, about 40 seeded species of the genus *Musa* have been recognised. This chapter describes the morphological and molecular evidence for the origin of bananas and the role of *Musa balbisiana* in the domestication and early cultivation of bananas. The chapter also reviews the archaeological evidence for early banana cultivation before considering the dispersal of bananas to Oceania, Africa, South and Southeast Asia.

Chapter 2 provides an overview of how the dominance of monoculture in banana cultivation has produced numerous agricultural, social and political problems. The chapter reviews the evolution of the banana industry and the advent of the dominance of the
Cavendish variety, before considering the crisis in Cavendish cultivation and a proposed new paradigm for future banana production. The chapter also examines the search for new banana varieties and looks ahead to future developments in the area.

Chapter 3 highlights the importance of banana in Africa as a food, cash and climate-resilient crop. However, average productivity in the region has declined dramatically to below 10t/ha compared with a potential of 60t/ha or more, whilst plantation longevity has also been drastically reduced. This chapter examines the composition and distribution of banana cultivars and assesses banana production systems, focusing particularly on banana production in Uganda as a case study of the problems faced by farmers in the region. The chapter reviews the range of challenges in banana production, including nutrient deficiencies, moisture stress and the impact of pests and diseases, as well as problems of market access. It examines solutions to these challenges such as the ways in which banana varieties might be improved to provide better resistance to pests and diseases.

The topic of Chapter 4 is the major role of bananas and plantains in global food security and household incomes in producing countries. As noted in Chapter 3, banana production and yields are affected by a variety of challenges, including availability of labour, soil degradation, access to clean planting material, management of pests and diseases, post-harvest losses and market access. This chapter reviews the range of research exploring constraints in relation to pre-production, production, post-harvest management and marketing in domestic value chains of cooking bananas and plantains from the perspective of smallholders. The chapter identifies opportunities for smallholders and other value chain actors for addressing these constraints and concludes with recommendations for future research.

Part 2 Improving practices across the banana value chain

The chapters in the second part of the volume review how to improve cultivation practices throughout the banana value chain. Chapter 5 addresses the fact that the sustainable management of bananas in farming systems requires knowledge of plant physiology, especially the pivotal processes of bunch formation. The chapter reviews what we know about formation of the inflorescence up to flowering (bunch emergence) emphasising interaction of the plant with the environment. The role of cool temperature in shortening the juvenile phase and long photoperiod in shortening the mid-vegetative phase of development is also discussed. By interpreting the bunch as a thyrse and hand as a cincinnus, the differentiation of functionally female flowers that form fruit and subsequently male flowers that do not form fruit is examined. In addition, this chapter highlights that hand formation and fruit number per hand are independent but coordinated processes. Genotype and environment determine the relationship between the number of hands/bunch and flowers/hand along the female peduncle. The chapter highlights the need to quantify the relationships that underpin new genotypes and management practices for sustainable banana production. A case study focusing on photosynthate availability and bunch formation in bananas is also presented.

The theme of Chapter 6 is how the process of propagating bananas, by taking a sucker, has allowed farmers to multiply their banana selections and share them. The banana sucker is a resilient form of planting material as the growing point is protected within the sucker, which contains a corm with a starchy store that allows the plant to readily
re-establish. This chapter briefly describes the basic anatomy of the banana plant required to understand the part of the plant used for propagation. The chapter then describes the various practical aspects of banana propagation using either conventional planting material or tissue culture plants and the benefits and disadvantages of each method. The chapter looks ahead to future research trends in the area of banana tissue culture.

Chapter 7 reviews how the availability of pest- and disease-free planting material is fundamental for successful banana cultivation. This chapter examines the key issues in the selection, establishment and management of a field germplasm collection, with a focus on how best to provide a reliable source of quality banana planting stock. The chapter discusses characterisation strategies for variety selection and includes a case study of banana cultivation in Queensland, Australia. The chapter addresses the sourcing of material for the germplasm collection and strategies to ensure freedom from pests and disease, and suggests future directions for research.

Chapter 8 reviews the main GAP-related certification schemes used in the sector: GlobalGap, Rainforest, EU Organic, Fair Trade and SA8000. While these schemes have made important improvements, growers have also seen them as a significant and growing bureaucratic burden. Some versions of standards risk being the certification of business as usual. The chapter shows how GAP certification procedures can be re-oriented to become more useful in benchmarking and improving productivity. It also argues that certification criteria should focus not just on specific inputs, but on broader ecological processes (such as soil ecosystem services). The chapter suggests using certification schemes to promote practices such as the use of cover crops and plant residues to protect soil, stimulate root activity and soil biology. As the chapter argues, a more holistic approach will help to achieve true sustainable intensification.

Chapter 9 highlights that fact that although a tropical climate is commonly thought to be more suited to banana production than a subtropical climate, banana yields obtained in the subtropics are excellent and, with good cultural practices, can be considered among the highest in the world. The relatively cool climate of the subtropics causes undesirable physiological phenomena and a long cropping cycle, but it has advantages as well. This chapter describes appropriate cultural practices designed to solve or minimize the climatic constraints on cultivation of bananas in the subtropics, including cultivation under greenhouse conditions.

Moving the focus onto a specific aspect of banana cultivation, Chapter 10 details the significant variation in banana production systems across the world, particularly at the level of soil management. However, as stated at the beginning of the Introduction, research into plant nutrition and soil management in relation to bananas has been limited. Bananas are unusual in their physiology and management, and the characteristics of the crop make it difficult to carry out standard fertilizer response experiments. The current scarcity of fertilization studies in bananas is perhaps surprising, given the significant economic consequences of fertilization costs. This chapter provides an overview of general aspects of soil management and then looks in more detail at crop nutrition. Focusing mostly on intensively managed systems where fertilizer use is highest, the chapter discusses a number of strategies for soil nutrition as well as advantages and disadvantages of each approach.

Chapter 11 highlights that bananas are one of the most widely traded crops globally, and with appropriate management, can be produced on a continuous basis. However, the journey from field to retail destination is a delicate, finely-tuned process which must be closely managed at every stage to ensure product safety and quality. This chapter
describes each stage of this journey, evaluating different strategies and challenges. The chapter reviews criteria for determining when to harvest a bunch, followed by a description of different harvesting and transport techniques to avoid crop damage. Post-harvest losses can be reduced through effective techniques of dehanding, washing, sorting and packaging. The chapter concludes with a discussion of future trends in banana cultivation, balancing the need to minimise production costs with increasing consumer concern for the environmental and human impact of banana production.

Complementing the previous chapter’s focus on harvesting, Chapter 12 highlights the importance of correct ripening for optimum taste, appearance, shelf life and consumer satisfaction. This chapter reviews the skills and technologies needed for successful ripening, together with innovations and recent developments. Advice on procedures and best practice throughout the supply chain is presented from the author’s unique experience in this sector.

Part 3 Assessing and improving sustainability

The themes of chapters in the third part of the volume address how to assess and improve the sustainability of banana production. As one of the world’s most traded fruits, bananas have attracted considerable attention for their social and environmental impact throughout the whole value chain. Chapter 13 describes concepts and tools for life cycle assessment (LCA) and carbon footprint (CFP) analysis as applied to the banana value chain. The chapter examines how LCA and CFP methods can be applied to analyse the environmental impact and sustainability of banana cultivation, and how it can inform banana labelling. It includes case studies of Ecuadorian and Peruvian banana value chains and looks ahead to future tools and practices that may be developed in this area.

The last two chapters of the book focus on ways of making cultivation of bananas more sustainable, with Chapter 14 highlighting that there is no single strategy for sustainable banana cultivation. Echoing Chapter 8, the chapter addresses the gap between implementation of global sustainability standards in the export industry based on a single banana variety, i.e., Cavendish, and the diversity of varieties, uses and production environments related to local food security and rural livelihoods. The gap between ecologically and socially-diverse production systems and management strategies relying on standardisation of agronomic practices complicates coordinated action working towards multiple solutions needed to improve sustainability. This chapter includes a case study of a major banana-producing region in the Philippines, representing a variety of banana production systems, which shows the importance of working towards a territorial approach that has the capacity to accommodate and connect multiple solutions to make banana cultivation more sustainable in the long term.

The last chapter of the volume, Chapter 15, addresses the fact that the cultivation of conventional bananas of the commercial Cavendish variety for export markets in the wet tropics requires a substantial amount of synthetic agrochemical input. Over the last 25 years organic banana production has soared in Latin America. This chapter describes organic banana production, identifying the key requirements for success, including location, soil quality and the use of rotations. The chapter also examines the importance of soil fertility and fertilization, disease management, weed management, and managing nematode and insect pests within organic systems.
1-aminocyclopropane-1-carboxylic acid 258
6-Benzylaminopurine (BAP) 131
5S 173
18L knapsack pump diaphragm sprayer 248
AAA varieties 13, 35, 46, 52, 65, 99, 102, 105, 133
ABB bananas and cultivars 6, 9, 10, 13, 14, 43, 46, 65–66, 105, 153
Acclimatisation stage 135
ACORBAT. see Association for Cooperation in Banana Research in the Caribbean and Tropical America (ACORBAT)
Active photosynthetic radiation (PAR) 209–210
Aerobic composting 329
African plantains 13–14
’Agbagba’ False Horn plantain 103
Agricultural Marketing Service (AMS) 319
Agrobacterium tumefaciens 52
Agroforestry systems 36
Aguirre, Fernando 21
Alliances and networks 68
Ammonium sulphate 326
AMS. see Agricultural Marketing Service (AMS)
Antagonistic phyllosphere microbes 332
Antibody-based diagnostic 46
Arbenz, Jacobo 26–27
Archaeobotanical evidence of banana cultivation 11–12
Ascorbic acid 131
Association for Cooperation in Banana Research in the Caribbean and Tropical America (ACORBAT) 322
Axial sucker 205, 207
Ayr Research Facility 152, 153, 155
Azoxyostrobine 334
BA. see Benzyladenine (BA)
Babuvirus 74
Backyard garden 36
Bacterial contamination 130
Bacterial wilt resistance 52
Bacteriophage Phi29 DNA polymerase 46
Banana backyard systems 36
Banana bunch top disease (BBTD) 74
Banana bunchy top virus (BBTV) 73, 121, 135, 343
Banana cultivars 183–184
Banana cultivation in Africa 33–57
cultivar composition and distribution 34–35
importance and challenges 33–34
improving banana varieties 50–53
marketing as constraint 54–55
moisture stress 41
nutrient deficiencies 40–41
pests and diseases 41–49
production systems 35–39
in Uganda 39–40
in subtropics 195–219
access to market 218–219
cultivars 216–217
description 195
greenhouse 207–216
influence of climate 196–199
plant protection 218
problems 200
removing healthy leaves 207
solving problems 200–207
see also Organic banana cultivation; Sustainable banana cultivation
Banana industry
Cavendish era 27–28
Cavendish in crisis 28–29
description 21–22
hunt for new varieties 29–30
monoculture development 23–24
dynamics 24–25
varieties and Cavendish 22–23
post-war developments 25–27
Banana intercrop system 36–37
Banana monocrop systems 37
Banana Research Program 53
Banana streak virus (BSV) 46, 73, 124
Banana suckers 117, 118–119
Banana value chain challenges 67–79
pre-production 67–70
processing 75–79
production 70–75
description 65–66
in Ecuador 296–297
enabling environment 79–80
Peruvian 294–296
and sustainability 282–283, 289–290
Banana weevil (BW) borer 42–43, 72–73, 121, 179–180, 337
Banana Xanthomonas wilt (BXW) 47
‘Bananos, Tecnologias de Produccion’ 322
Banavac plastic bag 262
BAP. see 6-Benzylaminopurine (BAP)
Barcode scanning system 128
Bateson–Dobzhansky–Muller model 10
BBTD. see Banana bunch top disease (BBTD)
BBTV. see Banana bunchy top virus (BBTV)
Beauveria bassiana 45
Benzyladenine (BA) 131
Benzylaminopurine 123
BG Door International BV 271
‘Big Mike.’ see Gros Michel
Biodiversity integration 182
Biology of Bananas and Plantains 322
Index

Biomass 175–176
Bioreactors 132
Biosecurity 146
Biotropic GmbH 291
Bioversity International 40, 147, 322
Black, Eli 28
Black leaf streak disease. see Black Sigatoka
Black Sigatoka 45, 73, 74, 144, 218, 261, 331–334, 342, 343
Bottom-up kaizen methods 179
Brazilian Agricultural Research Corporation 343
BSV. see Banana streak virus (BSV)
Bunch
age 237
covers 207
Bunch formation
aerial true stem growth 108–110
description 93–94
floral phase 97–99
overview 97
timing of events 97–99
formation of hands and fruit 102–108
genotypes 103–106
seasonal and edaphic conditions 106–108
gross morphology and 94–95
inflorescence 99–102
fruit-forming and non-fruit-forming 102
thyrse with cincinni 100–102
vegetative apex and external indications 99–100
phases of development 95–97
methodology 96–97
phases and ‘clocks’ 95–96
photosynthate availability and 110–113
discussion 112–113
materials and methods 110–111
overview 110
results 111
Business process re-engineering 173
BW. see Banana weevil (BW) borer
BXW. see Banana Xanthomonas wilt (BXW)
CA. see Controlled atmosphere (CA)
Cableway infrastructure network 240–241
CAC. see Codex Alimentarius Commission (CAC)
Caffery, Jefferson 24
Calcium nitrate 326
Calibration and maintenance 277
Callimusa 3–4
Carbamate insecticides 44
Carbofuran 44
Carbon footprint (CFP) 182, 188, 281, 285–286
Carbon Trust 284
Carson, Rachel 159–160
Cation exchange capacity (CEC) 328
Cavendish banana and cultivar 15, 22, 27, 29, 97, 99, 106, 124, 133, 182, 217–218, 310, 334, 342
Cavendish cultivar 15, 217–218
CCLAC. see Coordinating Committee for Latin America and the Caribbean (CCLAC)
CEC. see Cation exchange capacity (CEC)
Celloclim® 211
Cell suspension 126
Certification, principles of 291
Certified Organic status 319
CFP. see Carbon footprint (CFP)
Chaetanaphothrips spp. 338
Chiquita 21, 23–28, 29, 144, 155, 237, 306
Chiquita 2000 271
Chiquita International Services Group 271
Christian Science Monitor 26
Cinnamonus 100–102
CIRAD 186. see French Agricultural Research Centre for International Development (CIRAD)
Circular conveyors 248
Climatic changes 199
Climatic hazards 200
‘Clowd’ diseases 49
Codex Alimentarius Commission (CAC) 159, 160, 252, 321
Coefficients of determination 111
Cohn, Irving 25
Colaspis ostmarki 338
Commelina caroliniana 101
Continuous improvement 173, 179
Controlled atmosphere (CA) 336
Controlled release formulations (CRF) 344
Conventional banana production 331–332
Conventional breeding 50–52
Conventional planting material 119, 122–124
Cooking bananas 65, 75, 79
Coordinating Committee for Latin America and the Caribbean (CCLAC) 252
Copper-based fungicides 333
CORBANA. see Corporacion Bananera Nacional de Costa Rica (CORBANA)
Corporacion Bananera Nacional de Costa Rica (CORBANA) 322
Corporate Social Responsibility 307
Cosmopolites sordidus 42, 72, 149, 218, 337
Cost–benefit analysis 298
Cost competitiveness 78
Cover plants 341
CRF. see Controlled release formulations (CRF)
CRISPR Cas-9 technology 343
Crop
growth simulation models 228
residues 341
response 228
Crow rot and mould 334–337
Curve-fitting 111
Cytokinins 123, 131–132
Dale, James 29
DArT markers 6

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Index

Decision-making process 290
'Decree 900' 26
Defoliation treatments 110–112
De Laat Koudetechniek BV 271
Del Monte system 263
Department of Agriculture 230
Dessert bananas 35, 50, 65
Di-ammonium phosphate 326
Diaspis boisduvalii 339
Diploid AA cultivars 5–6
Disc-on-stump traps 44
Diseases
of banana 45–47
management 47–49
avoiding pathogens to new locations 47–48
Black Sigatoka 331–334
Crown rot and mould 334–337
enforcement procedure 49
good crop husbandry 49
inoculum management 49
Dispersal of bananas
into Africa 13–14
into Oceania 12
in South and Southeast Asia 14–15
Dole 23, 25–28, 162, 237
Domestication of bananas 10–11
Dow Chemical 162
DSSAT framework 229
‘Ducasse’ 153
Dulles, John Foster 26
Dusban 44
Dwarf Cavendish 101, 196, 199, 204, 216–217, 342
Dwarf off-types 133, 136
EAC, see East African Community (EAC)
EAHB. see East African highland bananas (EAHB)
Early banana cultivation
archaeological evidence for 11–12
domestication and 10–11
Earth Day 160
Earth Summit 160
East African Community (EAC) 80
East African highland bananas (AAA-EAHB) 35
East African highland bananas (EAHB) 13, 34–35, 43, 46, 52, 65, 107
Ecological intensification (EI) 161, 177, 179
‘The Ecology of Commerce: A Declaration of Sustainability’ 322
Eco-OK labelling 164
ECO-TOP ripening system 271
Ecuador, Banana value chain in 296–297
Edible seedless bananas 94
El. see Ecological intensification (EI)
Eisenhower (Dwight D. - US President) 26
‘El Pulpo’ 23
Endophytic bacteria 130
Environmental Protection Agency (EPA) 160, 338
‘Enyeru’ 107
Epigenetic changes 133
Equalisation period 275
EU Commission Regulation No. 354 319
EU Commission Regulation No. 889 319
EU Organic 163
Eurasia Connection 263
EurepGAP 160
European Joint Programming Initiatives 282
European Union (EU) Organic Agriculture label 165, 166–167
EX-ACT BVC. see EX-Ante Carbon-Balance Tool for Banana Value Chain (EX-ACT BVC)
EX-Ante Carbon-Balance Tool for Banana Value Chain (EX-ACT BVC) 293–294, 295
FAO. see Food and Agriculture Organization (FAO)
Farmer networks 68
Farmers and marketing strategy 55
Farm Management Plan 324
FDA. see Food and Drug Administration (FDA)
‘Female’ flowers 102
Fencing 146
Fertigation techniques 230–231
Fertilizer band 230
FHIA. see Fundación Hondureña De Investigación Agrícola (FHIA)
FHIA 17 50
FHIA 23 50
Field genebanks 144, 152
Finger diameter 237
First ratoon (R1) 205, 207
Flowering 111–112
Flower types 102
FOC race 1 46
FOC-resistant cultivars 29
FOC SR4. see Fusarium wilt Subtropical Race 4 (FOC SR4)
FOC-TR4. see Fusarium wilt tropical race 4 (FOC-TR4)
Fogging chamber 248
Followers 119
FONTAGRO project 174, 179
Food and Agriculture Organization (FAO) 159,
160, 161, 252, 282, 293, 304, 305, 307, 321
Food and Drug Administration (FDA) 252, 320
Food intercropping systems 35
The Food Safety Modernization Act (2011) 252
Ford, Henry 25
French Agricultural Research Centre for International Development (CIRAD) 322, 343
Fruit fill, degree of 237
Fruit selection processes 247–249
Full-leaf defoliation 112
Fundación Hondureña De Investigación Agrícola (FHIA) 29, 144
Fusarium oxysporum 45, 73, 119, 149, 153, 342
Fusarium wilt 23, 25, 26, 30, 45–46, 47–48, 65, 73, 73–74, 119, 121, 123, 135, 144, 218
Fusarium wilt Subtropical Race 4 (FOC SR4) 217
Fusarium wilt tropical race 4 (FOC-TR4) 21–22, 28, 29, 46, 74, 133, 162, 303, 310, 343
Fyffes 306

GAP. see Good agricultural practices (GAP)
Gassing procedure 275–276
Gates Foundation 29
GCTCV. see Giant Cavendish Tissue Cultured Variants (GCTCV)
Gender and banana plantations 68
Gene sequencing and manipulation 182
Genetic admixture 10
Germplasm conservation 124
case study 152–155
choosing site 145–146
crop management 150
description 143–144
dissemination of quality planting stock 152
objectives of field genebank 144–145
planting 149–150
quality control 151–152
sourcing material 147–149
GHG. see Greenhouse gas (GHG) emissions
Giant Cavendish Tissue Cultured Variants (GCTCV) 342
GlobalGap 160, 163, 164, 165, 167, 170, 172, 182, 184
Global Good Agricultural Practices (GLOBALG.A.P.) 304, 306
Global warming 199, 287
GLRA. see Great Lakes Region of Africa (GLRA)
GMO crops 184
‘Gold standard’ BSV diagnostic tool 46
Good agricultural practices (GAP)
in banana production 161–163
description 159–161
improving 172–182
bunch weight 174–175
crop nutrient and residue management 175–176
Fusarium Tropical Race 4 176–182
insect pests of the bunch 176
stand density 175
related certification schemes 163–166
scientific frontiers and implications 182–187
banana plant and rhizosphere microbiome 184–185
biodiversity for ecosystem services 185–186
biotic and abiotic stresses 183–184
integrated banana health and productivity 186–187
managing soil microbial community 184
and sustainable banana production 166–172
‘Good for Development’ certification framework 188
Gourmet Gardens Ltd 55
Government of Uganda 52
Grand Nain 133, 196, 199, 204
Great Lakes Region of Africa (GLRA) 34
Greenhouse gas (GHG) emissions 182, 281, 283–284, 287, 295
Greenhouse screening 185
Gros Michel 15, 23, 25, 27, 28, 29–30, 50, 65, 97, 102, 185, 217
‘Growth Stages of Mono-and Dicotyledonous Plants’ 322
HACCP. see Hazard analysis of critical control points (HACCP)
‘Hacer la césarea’ 197
Harvesting
bunch movement 239–241
description 235–236
determining criteria 237
alternatives 237–239
Hazard analysis of critical control points (HACCP) 163
Healthy leaves removal 207
Helicotylenchus multicinctus 42, 72
Hermaphrodite flowers 94, 102
High Noon (SH-3640) 217
High-ridge Banana Growers and Marketing Association 79
Home garden systems 35–36
Honduran Foundation of Agricultural Investigation 343
Horn plantain 104, 110
‘The Hotel Banana’ 23
Humic-acid-based soil amendments 330
ICM. see Integrated crop management (ICM)
IFOAM. see International Federation of Organic Agriculture Movements (IFOAM)
‘The IFOAM NORMS for Organic Production and Processing’ 321
IIED. see International Institute for Environment and Development (IIED)
IISD. see International Institute for Sustainable Development (IISD)
IITA. see International Institute of Tropical Agriculture (IITA)
Imazalil 334
Immunocapture (IC)-PCR 46
INIBAP. see International Network for the Improvement of Banana and Plantain (INIBAP)
Integrated crop management (ICM) 172, 174, 182, 185
Integrated pest management (IPM) 73
Interko/TH system 268
International Federation of Organic Agriculture Movements (IFOAM) 305, 321
International Institute for Environment and Development (IIED) 305
International Institute for Sustainable Development (IISD) 305
International Institute of Tropical Agriculture (IITA) 40, 50
International Labour Organization 165, 306
International Network for the Improvement of Banana and Plantain (INIBAP) 322
International Organization for Standardisation (ISO) 304
International Plant Protection 160
International Trade Center (ITC) 160, 165, 166–167
International Transit Centre 147
In vitro banana propagation 132
IPM. see Integrated pest management (IPM)
Irrigation system 41, 200
ISO. see International Organization for Standardisation (ISO)
ISO 14001 290, 304, 306
ISO 14040 284, 289
ISO 14044 284
ISO 14067 289
ITC. see International Trade Center (ITC)
ITC Standards Map 169
Japanese Agricultural Standards 319
‘Kaizen’ business improvement 173
Kellogg, Frank Billings 24
Kokkeel, Willem 263
Lady Finger cultivar 73, 217–218
LCA. see Life cycle assessment (LCA)
L-cysteine 131
Leaf
  and dust abrasion 198
  pruning 175
  tearing 198
‘Lean’ organization 173
Life cycle assessment (LCA)
  banana value chain and sustainability 282–283, 289–290
  climate change and value chains impact 283–284
  environmental impact and carbon footprint 286–287
  environmental issues awareness in agriculture 281–282
  integrated socio-economic carbon footprint
  banana value chain tool 292–297
  case studies 294–297
  FAO EX-ACT 293–294
  labelling and certification 290–292
  strategic research and development orientations 298
  systematic carbon footprint appraisal 298
Linear conveyors 248
MA. see Miniature modified atmosphere (MA)
Makerere University 40
MAP. see Modified atmosphere packaging (MAP)
Maroochy Research Facility 152, 153
Marquez, Gabriel Garcia 24
Mass spectrometry 184
Maximum Residue Limits 164
‘Mbang Okon’ French Horn plantain 103
Mbwazirume Highland banana cultivar 45
McDonald 25
Mealy bugs 176, 185, 337, 339–340
Meloidogyne spp 42
Meristem culture 129–130
Metabolomics information 156
MGIS. see Musa Germplasm Information System (MGIS)
Micropropagation 124, 125–126, 133
Miniature modified atmosphere (MA) 335, 336
Ministry of Agriculture Forestry and Fisheries 319
Miss Chiquita 25
Model T 25
Modified atmosphere packaging (MAP) 336
Moisture stress management 41
Moko/Bugtok disease 74–75
Molecular breeding 52
Molecular fingerprinting 156
Mono-ammonium phosphate 326
Monocropping systems 36
Mouse Ear 341
Mulching 41
Musa acuminata 3–5, 6, 9–11, 15, 94–95, 101, 118, 196
Musa balbisiana 3–4, 6, 9–11, 15, 47, 94, 101, 118, 124
Musa cropping systems 37–39
Musa Germplasm Information System (MGIS) 147, 151, 156
MusaNet Technical Guidelines for the Safe Movement of Musa Germplasm 124
Musa paradisiaca 3
Musa rubra Kurz 4
Musa sapientium 3
Musa velutina 101
Mycosphaerella fijiensis 74
NAADS. see National Agricultural Advisory Services (NAADS) Act
Nakasongola District Farmers Association 79
Index

‘Nakyetengu’ 52
NARO. see National Agricultural Research Organization (NARO)
National Agricultural Advisory Services (NAADS) Act 80
National Agricultural Research Organization (NARO) 40, 43, 50, 52, 53, 55
National Land Policy 79
National Organic Program (NOP) 319, 321, 331, 338
National Research Council 166
Nematicides 179
Nematodes 42, 72–73, 121, 123, 144, 186–187, 337
Newsweek 26
New York Times 23, 25, 26
NGOs. see Nongovernmental organisations (NGOs)
Nitrogen 40, 71
Non-banana-growing areas 53
Nongovernmental organisations (NGOs) 304, 307
NOP. see National Organic Program (NOP)
Northern Uganda, non-banana-growing areas of 53
Nucleic acid sequencing 184
NUE. see Nutrient use efficiency (NUE)
Nutrient cycling 71
replenishment 40–41
Nutrient use efficiency (NUE) 226, 229, 230
Nutrition and soil management assessing nutrient requirements 224–229
accounting for relationships 225
balances 225–227
flows to plants 227
foliar analysis and crop NUE 228
role of models 228–229
status 224–225
tillage and drainage 228
description 223–224
fertilizer use recommendations 229–230
precision application of nutrients 230–231
‘Obino L’Ewai’ French Horn plantain 104
Off-types 132–134
One Hundred Years of Solitude 24
Organic banana cultivation certification 319–320
compost production and usage 327–328
making compost 328–329
organic amendments benefits 328
root-system health 329–331
control in 332–334
demand and markets 318
description 317
disease management 331–337
Black Sigatoka 331–334
Crown rot and mould 334–337
fertilization and irrigation 327
insects 337–340
banana fruit scarring beetle 338–339
mealy bugs and scale 339–340
red rust thrips 338
location 323
nematodes and weevil borers 337
nitrogen 326
organic and non-organic fertilizers 327
organic standards 320–321
phosphorus 326
potassium 326
rotations 324–325
soil 323–324
soil types and nutrition 325
sources and guidance 321–322
sustainability 318–319
weed management 340–341
cutting and mowing 340–341
ground cover 341
see also Banana cultivation; Sustainable banana cultivation
Organic certification 160, 166
Organic Consumers Association 320
Organic farming 320
Organic fertilizers 176, 330–331, 341
Organic Materials Review Institute 321
Organic Production and Labelling of Organic Products 319
Organic Standards Magazine 321
Organic Trade Association (OTA) 320
Organochlorides 44
Organophosphates 44
Origin of banana 4–9
Oritos 250
OTA. see Organic Trade Association (OTA)
Pacific plantains 12
Packaging system 249–252
Packing house operations 241–245
Panama disease. see Fusarium wilt
Panama-disease-resistant commodity variety 29
PAR. see Active photosynthetic radiation (PAR)
Paraffin polyolefin wrap protection 335
Paraviruses 124
PAS. see Publicly Available Specification (PAS)
PCR. see Polymerase chain reaction (PCR)
Pentalonia nigronervosa 74
Peruvian banana value chain 294–296
Pests of bananas 41–43
management 43–45
biological control 44–45
chemical control 44
clean planting material 43  
crop rotation 44  
post-harvest residues destruction 43–44  
weevil trapping 44  

Phenolic production 131  
Phenotyping 156  
Photoperiod response 96  
Photosynthate availability 112  
Phytoliths 11–12  
Phytosanitary barriers 219  
Pinto’s Peanut 341  
Pisang Awak A genome 14–15  
Pisang Mas. see Oritos  
‘Pisang Siem’ 15  
Plaesius javanus Erichs 44  
Plantain – cacao systems 36  
Plant and rhizosphere microbiome 182, 186  
Plant diversity 185  
Planting date for bananas 202–203  
Planting density and spatial arrangement 204–205  
Plant propagation methods  
bits and suckers 119–122  
advantages 120  
disadvantages 121–122  
description 117–118  
evolution 118  
liquid culture systems 132  
morphology and vegetative propagation 118–119  
off-types 132–136  
elongation and rooting 134  
nursery production 134–135  
screening and roguing 136  
temperature 135–136  
propagation using conventional planting material 122–124  
tissue culture 124–132  
advantages and disadvantages 125  
after culture initiation 131  
case study 126–127  
indexing banana for bacteria 130–131  
material selection for culture initiation 127–130  
micropropagation 125–126  
multiplication 131–132  
Polyethylene (PE) covers 209, 210–211, 213  
Polymerase chain reaction (PCR) 46  
Postharvest treatment 248–249  
Potassium 40, 71–72  
chloride 326  
sulphate 326  
‘Poyo’ Cavendish 103  
Pratylenchus goodeyi 42, 72  
Pratylenchus spp. 149  
Precision breeding, see Molecular breeding  
Pre-production challenges  
access to quality planting material 68  
labour for land preparation 67–68  
land tenure and fragmentation 69–70  
social constraints 68–69  

Primophosethyl 44  
Processing challenges  
marketing challenges 77–79  
post-harvest losses 75–76  
value adding 76–77  

Production challenges  
access to fertilisers and pesticides 70–71  
bacterial, fungal and viral diseases 73–75  
climate variability and change 75  
crop management practices 72  
labour for plantation management 70  
pests 72–73  
soil fertility and water/moisture stress 71–72  

Product sensors 275  
ProMusa website 123  
Proto-cultivars 5  
Provitamin A enhancement 52  
Pseudostem trap 44  
Publicly Available Specification (PAS) 284  
Pueraria phaseoloides 175  

QBAN. see Quality Banana Approved Nursery (QBAN)  

Quadratic equations 111  

Quality Banana Approved Nursery (QBAN) 124  
Quality planting material 68, 79  
Queensland Department of Agriculture and Fisheries 152  
Queensland University of Technology 343  

Radopholus similis 42, 72, 149, 337  
Rainfall 75  
Rainforest/Sustainable Agriculture Network certification 164  

Ralstonia solanacearum 149  
RCA. see Rolling-circle amplification (RCA)  
Red Dacca 250  
Red rust thrips 185  
Re-engineering approach 179  
Regulation (EEC) No. 2092 319  
RFLP markers 5  

Ripening process control sheet (RPCS) 273, 276–277  

Ripening systems 76  
cycles 259–260  
description 257  
factors affecting 258–259  
quality control 273–277  
supply chain 261–266  
discharge 264  
distribution 265–266  
growing 261–262  
loading 264  

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Index

packing 262–263
pre-cooling 263
ripening facility 265
transport 263
technologies and rooms 266–271
Rodale, J. L. 329
‘The Rodale Book of Composting’ 329
Rodale Press 329
Rolling-circle amplification (RCA) 46
RPCS. see Ripening process control sheet (RPCS)
SA8000 163, 165, 187, 290
Scale insects 176, 185, 339–340
Shoot-tip culture 129
Sigatoka disease. see Yellow Sigatoka
Silent Spring 160
Silver, Frank 25
SIMBA model 186, 229
Smallholder farmers 77
Smallholder intercropping systems 38
Smallholder monocropping systems 38
Smith, E. F. 45
Socio-economic LCA focus 286
Soil
microbiology and ecology 182
moisture 41, 71
nutrient deficiencies 71
preparation 150
Soil-borne pathogens 146
‘Soil Degradation and the Rise of Organic Nutrition’ 322
Soil-free potting mix 135
Solar radiation 108
Somaclonal variation 132, 133, 147
Somatic embryogenesis 126
Sooty mold 339
South Johnstone Research Facility 152
SSR markers 6, 9
Standard Fruit. see Dole
Steering Committee of the State-of-Knowledge Assessment of Standards and Certification 2012 167
Stop climate change seals 291
Student’s t-tests 111
Subsistence and commercial 36
Sucker management
direction of selection 205, 207
stage of parent plant development 205
Sucriers. see Oritos
Sul-Po-Mag 326
Sustainable banana cultivation
banana producers in Philippines 309–310
description 303
and diversity in production 308–309
in food security 308
genetic diversity 309
in mixed cropping systems 308
limits of standards 307
range of standards 304–307
see also Banana cultivation; Organic banana cultivation
Swennen, Rony 29
Sword sucker 119, 127
Synthetic urea 326
System analysis 182
Tariff barriers 219
Tarp system. see Del Monte system
TDZ. see Thidiazuron (TDZ)
Temperature 75, 108, 135–136, 196
Temporary immersion systems (TISs) 132
Thiabendazole 334
Thidiazuron (TDZ) 123, 131
Thyrs 100–102
Time 26
Tin Pan Alley 25
TISs. see Temporary immersion systems (TISs)
Tissue culture 53
Training Manual for Organic Agriculture in the Tropics 321
Transitional and transformational approaches 188
Triploid AAA genome cultivars 6
True plantains 65
Turbana label 306
Twisting suckers 127
Uganda, banana production in 39–40
Ultraviolet (UV) radiation 210
UN. see United Nations (UN)
Underground corm 118
United Fruit. see Chiquita
United Nations (UN) 160, 164
Universal Declaration of Human Rights 165
‘Unti Belanda’ 15
UPD 258, 273, 274
U.S. Department of Agriculture (USDA) 319, 331
USDA Organic Standards 319
UV. see Ultraviolet (UV) radiation
Vacuum bag packing 335
Value chain actors 68
Value chain analysis 282
Ventilation 276
Wageningen University and Research 343
Wages in banana plantations 68–69
Washington State Department of Agriculture (WSDA) 321
Waste 173
Water footprint 182, 188
Water sucker 119
WBF. see World Banana Forum (WBF)
Index

West African rainforest plantains 13–14
White fluorescent lighting 126
Whitman, Ed 26
Wild bananas 93–94, 103
Williams 133, 136, 153, 196, 204, 217
World Animal Health 160
World Banana Forum (WBF) 293, 298
World Health Organization 159, 252, 321
World Trade Organization (WTO) 160, 164

WSDA. see Washington State Department of Agriculture (WSDA)
WTO. see World Trade Organization (WTO)

Xanthomonas campestris pv. Musacearum 47
Yellow Sigatoka 218
Zemurray, Samuel 26, 27