BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Achieving sustainable cultivation of cassava

Volume 2: Genetics, breeding, pests and diseases

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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 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 though 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 ethno-biological 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.

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