BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Achieving sustainable cultivation of mangoes

Edited by Dr Víctor Galán Saúco, Instituto Canario de Investigaciones Agrarias (ICIA), Spain

Dr Ping Lu, Research Institute for the Environment and Livelihoods, Charles Darwin University, Australia

burleigh dodds SCIENCE PUBLISHING

Contents

Introduction

Native to Southeast Asia, mangoes are now one of the most widely cultivated fruits, grown in over 100 countries across Asia, Africa and the Americas as well as Southern Europe. Mangoes are mainly consumed as fresh fruit, but also used widely in juices and in cooking, and are valued for their nutritional and nutraceutical properties. Drawing on an international range of expertise, this book focuses on ways of improving the cultivation of mango as a food crop at each step in the value chain, from breeding through to post-harvest storage. Part 1 discusses advances in understanding tree growth, flowering, pollination and fruit development, as well as developments in marker-assisted breeding. Part 2 reviews improvements in cultivation practices, including organic and greenhouse cultivation. Part 3 covers post-harvest management and quality, whilst Part 4 of the book assesses disease and pest management.

Part 1 Genetic improvement and plant physiology

Chapter 1 focuses on the development of molecular tools to improve understanding of the biology of mango and many other crops. This chapter reviews advances made in mango genetics using different molecular tools, including biochemical markers and DNA research employing restriction fragment length polymorphism (RFLP), randomly amplified polymorphic DNA (RAPD) and amplified fragment length polymorphism (AFLP). The chapter looks ahead to current and future developments in the field, including next-generation sequencing technologies and localization of genes of interest for breeding purposes. The chapter also offers suggestions for further reading on the subject.

Chapter 2, entitled 'The genetic diversity of mangoes', consists of a table listing over 100 mango cultivars selected on the basis of their local and global importance. The description of cultivars is based on over thirty years of research conducted by Fairchild Tropical Botanic Garden in Miami, Florida. The table lists cultivar name, tree size, fruit characteristics and fruiting season as well as additional information such as origin. The table is accompanied by colour photos of these *Mangifera indica* cultivars.

Chapter 3 makes clear the mango tree canopy is a carbohydrate factory, via photosynthesis, and a support for reproduction; it is also the place where vegetative growth occurs and the tree develops. The spatial and temporal proximity of vegetative and reproductive growth in the mango canopy leads to complex interactions. This chapter reviews the current state of knowledge of vegetative growth and deciphers these interactions, in order to inform more efficiently managed cultivation practices and future research. The chapter presents the architectural model of the mango tree. The basic structural entity, the growth unit, is defined and its morphology, growth and development are reviewed. The chapter then discusses the relationships between the growth unit and canopy development, along with the effects of environmental and endogenous factors on tree phenology. Finally, the interactions between vegetative growth and reproduction are described.

Chapter 4 addresses flowering, pollination and fruit development, beginning with vegetative shoot formation and then the plant's induction, initiation and floral differentiation. The number of fruits will depend upon the success of the pollination, fertilization and fruit

set processes. The chapter also analyses the genes governing flower development and the processes of pollination and fertilization. It suggests future research trends in this area and recommends further reading on the subject.

Part 2 Cultivation techniques

Chapter 5 focuses on the fact that mango is grown in more than 100 countries, and is a commercially important fruit for many countries in the tropics. However, mango cultivation faces various problems which require urgent attention if sustainable production is to be achieved. This chapter reviews the factors and constraints that affect mango productivity in the tropics. The constraints related to soil, climate (including temperature, altitude and climate change), orchard management (from new mango orchards to high-density orchards), irrigation and nutrition, are discussed. In each case, strategies are presented to address these constraints and promote sustainable mango cultivation.

Chapter 6 builds on Chapter 5 by pointing out that although mango is well adapted to hot, tropical climates, it can also be grown in the subtropics with mild winters. Under such conditions, the cooler winter temperatures compared to tropical winter temperatures, improve flower induction and cause early bearing and lower annual growth rates, which help to control size and favour high-density plantings. There are also disadvantages to growing mango in the subtropics: cold spells and low temperatures can damage vulnerable young trees or areas of young growth, or can induce flowering of very young trees in the nursery, causing premature aging of inadequately managed plants. This chapter reviews the differences between mango cultivation in tropical and subtropical climates, including out-of-season production, and explores the factors necessary for successful subtropical cultivation.

As Chapter 7 points out, in countries such as Japan, Spain and Portugal, mangoes are cultivated in greenhouses. Specific techniques are used to maximize production and quality and to ensure efficient summer and winter harvesting. This chapter describes greenhouse practices of mango cultivation, including the control of flowering, care of fruit and pest control. Specific techniques include training and pruning, fertilization and irrigation, fruit thinning and bagging as well as harvesting and tree replacement.

Chapter 8 makes clear that there are many advantages to establishing high-density mango hedgerows using small trees. This method of cultivation means the terminal-shoots, inflorescences and fruits on such trees are within easy reach of farmworkers. The fruits, as well as branches and new shoots, can be specifically targeted for fungicide or pesticide application. This chapter describes the stages of a 3 m x 1 m Tommy Atkins mango orchard, from the time of its establishment to the time the trees fill their space in the orchard row and are fully bearing. It gives an account of management actions required for sustained maximal production, describing the benefits of the reduced time from planting until the trees attain optimal canopy cover and maximum fruit production. The chapter assesses the extent of small tree-growing systems to date.

Chapter 9 discusses the fact that in recent years the demand for organic mango has increased. Few technologies are currently available to support organic mango production systems in the main mango-growing regions. This chapter explains current technologies for sustainable organic mango production in the field and post-harvest processing. The chapter describes the importance of climate and soil selection, selection of cultivars and

rootstocks, and soil preparation and planting. The chapter also addresses issues arising from the management of established mango orchards including weed control, irrigation, and pest and disease management. Finally, the chapter compares organic and conventional systems of mango production.

Chapter 10 highlights that the irrigation requirements of mango have not been adequately investigated, and very few studies have been conducted on regulated deficit irrigation (RDI) strategies at different phenological stages. The chapter suggests how research in the field of irrigation and fertilization can help solve the challenges faced by the mango industry and be translated into practical outcomes for farmers by making mango production more sustainable. In order to achieve this goal, based on an extensive and detailed review of the most relevant research on these topics, the chapter identifies potential areas for applied research that can significantly contribute to more sustainable mango agriculture in small, medium and large mango farms in developed and developing countries. The chapter also includes a detailed case study.

Part 3 Post-harvest management

Chapter 11 explores mango fruit quality from the perspectives of the grower, the packer, the retailer and the consumer. The chapter examines specifications for fruit at harvest maturity and at commercial maturity (eating stage), as well as technologies for monitoring relevant attributes, including machine vision estimation of canopy flowering, temperature logging for heat sum fruit maturation models, and tools for the estimation of fruit size, colour and dry matter content. The chapter discusses the use of dry matter content as an eating quality specification for guiding harvest decisions. The chapter also addresses the use of machine vision in the context of estimating fruit number and fruit size in the orchard and estimating fruit surface defects in the packhouse. Finally, the chapter discusses post-harvest tools to monitor fruit ripeness including the measurement of temperature, colour, firmness, ethylene and CO_2. The chapter includes an example decision support system that uses heat sums and dry matter levels to guide the decision to harvest.

Chapter 12 focuses on the fact that post-harvest deterioration in the quality of mangoes is largely determined by pre-harvest factors, ranging from the cultivar grown to orchard management and harvest practices. This chapter describes mango fruit anatomy and development, and the changes related to ripening in mangoes and the pre-harvest, in-harvest and post-harvest practices that can lead to deterioration or damage. The chapter also addresses measures that can be taken to reduce the risk of fruit deterioration and damage, including fruit thinning and individual fruit bagging or netting. The chapter discusses viable and cost-effective solutions to mango damage and deterioration and looks ahead to future trends in this area. Building on Chapter 12, Chapter 13 reviews current research on the preservation of fruit quality. It also looks at ways of reducing post-harvest damage and loss by employing suitable technologies and knowledge during post-harvest operations, storage management, transportation and marketing of mango fruit.

Chapter 14 highlights that mangoes can be considered a major source of bioactive compounds, notably vitamin C, phenolics (mainly gallic acid) and carotenoids. This chapter reviews the health benefits associated with the antioxidant properties of these compounds, which potentially offer protection against cardiovascular diseases, metabolic diseases and cancers. The chapter examines specific cell, animal and clinical studies that

suggest mango pulp, juice and extract are effective against metabolic diseases and certain forms of cancer. The chapter considers approaches that can be used to increase bioactive compounds in mangoes either before or after harvest, and includes a case study on the use of pulsed light to increase concentrations of vitamin C, carotenoids and phenolics.

Chapter 15 focuses on the fact that mango production systems have seldom been studied using the technique of Life Cycle Assessment (LCA), which is an international standard for evaluating the environmental impacts of agri-food value chains. Important challenges are associated with the application of LCA to the environmental evaluation of fruit systems in general and mango in particular. This chapter describes the core principles of LCA methodology, the state of the art of LCA for fruits and associated key challenges. The chapter makes up-to-date recommendations for the use of LCA. The chapter then presents and discusses the first complete LCA case study for mango exported from Brazil. Finally, the chapter analyses the environmental challenges faced by mango systems across the world, highlighting the great potential of LCA to achieve more eco-friendly production and consumption of mango.

Part 4 Diseases and pests

Chapter 16 highlights that mango is affected by a great number of fruit, foliar, stem and root diseases. This chapter covers diseases that seriously impact the crop. Their significance, geographical distribution and history are outlined, and the symptoms, causal agent(s) and epidemiology of each are detailed with emphasis on their management.

Chapter 17 builds on Chapter 16 by providing an overview of Integrated Pest Management (IPM) in mango cultivation. IPM is the compatible use of various methods to control pests, which include biological, cultural and chemical control. Biological control is based on using predators, parasitoids and pathogens to reduce pest populations. Cultural control is based on management practices, for example, pruning to create an environment non-conducive to pests and to improve spray coverage. Chemical control should be used as a last resort and should be restricted to selective and less disruptive insecticides. Regular pest and beneficial insect monitoring is an integral component of IPM with interventions only applied when pest numbers reach a certain threshold. Four case studies are included to illustrate how IPM works in practice.

Index