

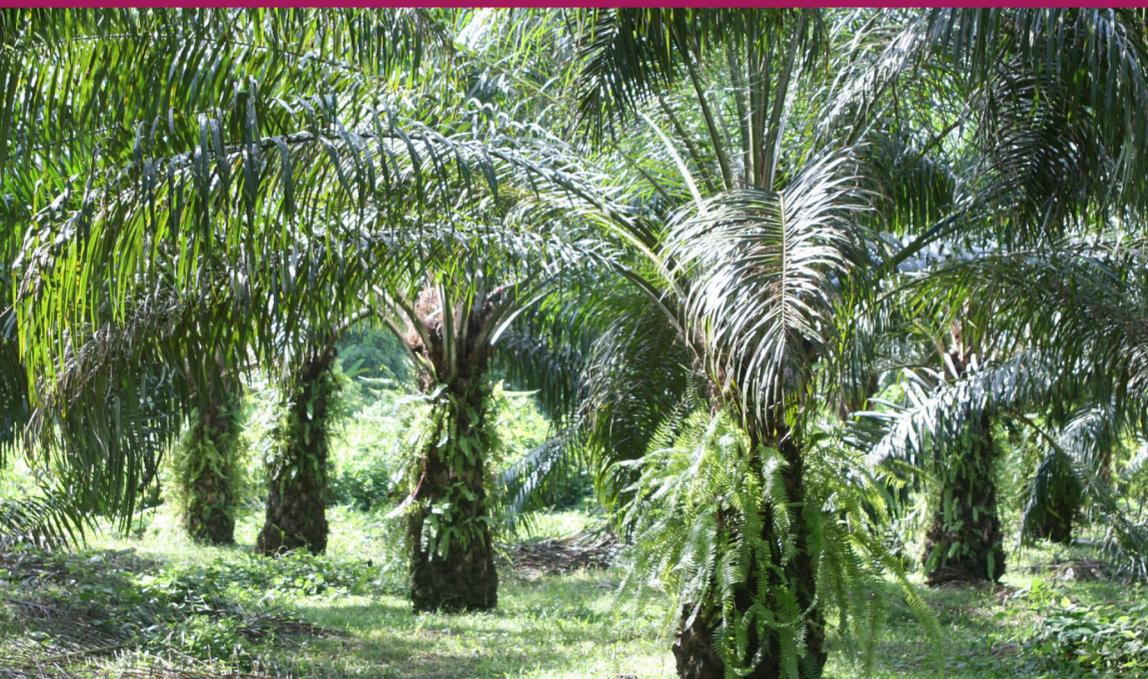
BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Achieving sustainable cultivation of oil palm

Volume 1: Introduction, breeding and cultivation techniques

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Introduction

Oil palm is widely cultivated in tropical countries for use in food and feed, personal care products and other applications such as biodiesel. Oil palm cultivation faces a range of challenges, such as its environmental impact (deforestation and biodiversity loss) as well threats from pests and diseases. There is an urgent need to make oil palm cultivation more efficient and environmentally sustainable.

These challenges are addressed in the two volumes of *Achieving Sustainable Cultivation of Oil Palm*:

- Volume 1: Introduction, breeding and cultivation techniques
- Volume 2: Diseases, pests, quality and sustainability

The chapters in Volume 1 review the latest developments in conventional and marker-assisted breeding, as well as transgenic approaches, as well as assessing ways of assessing and optimising yields through integrated approaches relying on precision agriculture aimed at fine tuning nutrient and soil management.

Part 1 Setting the scene

The first part of the volume begins by reviewing trends in production and key challenges facing the sector. Chapter 1 addresses the growth of the palm oil market, key actors and trends. For many years palm oil has proved to be the most productive, highest yielding oil crop, with a yield 4 to 10 times higher than any other oil crop. This has driven palm oil to become the most consumed vegetable oil in the world. The chapter provides an overview of oil palm cultivation and palm oil production throughout the world, with a particular focus on Indonesia and Malaysia, and describes the growth of the palm oil industry and the nature of the global market. The chapter also addresses the diverse ecological and social impacts of palm oil and suggests future directions for sustainable palm oil production.

Chapter 2 moves from the commercial market to consider research trends in oil palm cultivation. Since its establishment as a commercial crop in Malaya in 1917, palm oil has become the most important vegetable oil traded in the world. Its standing in the world market is attributed to the oil's versatile applications, stable supply and affordability. With the estimated global world population reaching nine billion by 2050, the supply of palm oil must grow to help meet the demand for vegetable oils. The chapter summarises the trends in research which have been driven by key challenges faced by the industry. It covers the establishment of oil palm as an economic crop, the improvement of yield by selective breeding, the use of genomics to expedite research and a holistic approach to remodeling cultivation systems for eco-efficiency, with the goal of achieving cultivation of oil palm with minimal environmental impact.

Following on from the aspirations for oil palm cultivation outlined in Chapters 1 and 2, Chapter 3 addresses the issues of achieving sustainable oil palm cultivation on the ground via detailed case studies drawn from Indonesia, Colombia and Cameroon, which are compared and contrasted. The chapter discusses the conceptualization of sustainable pathways in oil palm production and the background to oil palm production in

three contrasted producing countries which involve different groups of stakeholders with different production goals. The chapter outlines the challenges of sustainable production pathways and sustainability initiatives. Finally, it considers the actors, regulations and practices in the dynamics of sustainability that may make sustainable production possible in Asia, South America and Africa.

Building on Chapter 3, Chapter 4 deals with the role of governance and land tenure in regulating the oil palm boom. Oil palm expansion has delivered economic development in host countries, including indirect benefits for local infrastructure development and rural poverty reduction, as well as multiplier effects for the national economies. However, its development has often come at the cost of basic rights and to the detriment of biodiverse, carbon-rich tropical forests, with local communities sometimes evicted from their lands and precious ecosystems destroyed.

Chapter 4 identifies several structural constraints to better governance, and argues that these must be addressed in order to build more sustainable and inclusive oil palm supply chains and landscapes. The chapter lays out the conceptual framework of palm oil governance, identifying the key action arenas and actors. The chapter explores the institutional architecture and critical problems affecting the palm oil governance complex, while highlighting major gaps in the governance of the commodity chain.

Part 2 Plant physiology and breeding

The focus of the second part of the volume is on developments in understanding oil palm physiology, genetics and genetic diversity, as well as their application to improved breeding techniques. Chapter 5 examines advances in understanding oil palm reproductive development. As for many other crops, yield components of the oil palm rely partly on the optimal implementation of its reproductive development. As a result, studies focusing on the mechanisms underlying sex ratio determination, inflorescence development or fruit maturation have rapidly multiplied, significantly improving our understanding of these critical processes. The chapter describes the impact of sex ratio, inflorescence and flower development on oil palm yields and describes the processes of fruit development and shedding and their importance, as well as oil acidification. The chapter looks ahead to the likely future impact of climate change and developments in this area that may increase the sustainability of oil palm cultivation.

Chapter 6 develops Chapter 5's focus on oil palm breeding by examining the importance of genetic resources in the implementation of efficient strategies of genetic improvement. Oil palm planting materials have been generated from an extremely narrow genetic base, and it has been generally recognized that the narrowness of the genepool is a major obstacle towards increasing yields in many crops. The chapter discusses the work undertaken by the Malaysian Palm Oil Board to broaden this genetic base. It also examines ways of assessing genetic diversity in oil palm, through the analysis of fruit forms and types, morphological traits and genetic markers. The chapter also reviews methods for the conservation of oil palm collections and ways of utilizing germplasm in order to develop improved varieties which constitute the basis of sustainable plantations.

Chapter 7 follows on from Chapter 6's focus on oil palm genetics to consider advances in conventional oil palm breeding techniques. At the beginning of the twentieth century, oil palm was a semi-wild crop which had not been subjected to modern breeding

techniques. The chapter discusses oil palm breeding objectives, breeding methods and data collection methods currently in use; it then reviews the impacts and progress of oil palm breeding programs. Finally, the chapter considers seed production and future trends in oil palm breeding.

Returning to the theme of genetics, the focus of Chapter 8 is on advances in marker-assisted breeding of oil palm. Oil palm, with its long breeding cycle and large land requirement for breeding trials, can be considered a suitable candidate crop for marker assisted selection (MAS). The chapter explores the applications of MAS in oil palm breeding, including pedigree testing and the prediction of monogenic and quantitative traits. The chapter shows that MAS enables accurate tagging of markers related to polygenic traits, a prerequisite for their integration into oil palm breeding strategies, and suggests future lines or research.

Complementing the themes of the preceding chapter, Chapter 9 addresses advances in genetic modification of oil palm. Transgenic crops are generated through recombinant DNA methods to alter gene expression in order to create new varieties for breeders that may be either difficult or impossible to produce using conventional approaches. Over the past few decades, transgenic methods have been successfully applied to develop genetically modified (GM) varieties of the major oilseed crops. The chapter reviews research efforts for production of GM oil palm plants over the past 20 years. Although these efforts have yet to result in stable lines of commercially useful GM varieties of oil palm, there are good prospects that the greatly improved knowledge of genomics coupled with advanced technologies such as genome editing will be successful in the future, provided it meets public approval.

Part 3 Cultivation techniques

The final part of the book discusses developments in oil palm cultivation practices. Chapter 10 examines the modelling of crop growth in order to achieve higher oil yields. Since the development of the first semi-mechanistic oil palm model, OPSIM, the development of new models has increased in frequency, aiming to take into account aspects of oil palm physiology and the physical processes and causal relationships between the environment and the crop. The chapter describes the development of a new oil palm growth and yield model called PySawit. The chapter discusses the evaluation of PySawit's accuracy when its predictions were compared with several measured parameters of growth and yield in oil palm. The chapter includes a full explanation of the methodology of the model and discussion of its results, and explores the modeling of meteorology, photosynthesis, energy balance, soil water and crop growth.

Continuing the theme of improved agricultural practices, Chapter 11 addresses efforts to improve soil and nutrient management in oil palm plantations. Soil health is increasingly regarded as a key factor in oil palm nutrition and productivity. The chapter presents the current state of knowledge about soil and nutrient management through several examples of efficient and productive oil palm cultivation. The chapter highlights the challenges which still need to be addressed in order to make the crop more sustainable in the long term while considering some new concepts in plant nutrition and soil fertility management. The chapter also considers the potential of new technologies such as sensors and drones. The chapter considers key issues relating to soil fertility, nutrient management, mineral nutrition and planting materials, and focuses particularly on issues affecting smallholders.

Complementing Chapter 11's focus on soil management, Chapter 12 focusses on maintaining soil health in oil palm cultivation. Many existing oil palm plantations were established after clearing tropical rainforests. In tropical soils under forest, the topsoil is where the fertility lies due to its physico-chemical properties, developed through an accumulation of organic matter and intense biological activity. The properties of this topsoil change rapidly in the first four years after felling, but it has been reported that the topsoil then evolves towards a new, stable chemical state. A central challenge is therefore to ensure that this new stable state possesses the properties that enable high yields. The chapter considers the key issues and challenges in maintaining soil health. It then reviews the effects of management practices in oil palm plantation on soil biological activity, and considers the potential benefits of biomass recycling.

The volume's final chapter, Chapter 13, considers the increasingly important issue of palm oil's use as biomass for biofuel. The use of fossil fuels depletes the world's limited supply of coal, oil and gas, and releases stored CO₂ into the atmosphere. Biofuels, derived from biomass, are renewable and carbon neutral, because consumption merely releases CO₂ taken from the atmosphere by the growing biomass. However, increasing the use of biofuels could also increase the pressure on ecosystems which must support the production of additional biomass. The chapter assesses the sustainability of biofuels, discusses their production and economics, and considers levels of government support for production and related geopolitical issues.

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