BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Achieving sustainable cultivation of sugarcane

Volume 1: Cultivation techniques, quality and sustainability

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Introduction

Sugarcane is the source of about three quarters of the world's sugar, and is grown widely in the tropics and sub-tropics. Despite rising demand, average yields have not increased significantly, partly because of continued vulnerability to pests and diseases. In addition, cultivation has been seen as damaging biodiversity and soil health with a negative effect on both yields and the environment.

These volumes on achieving sustainable cultivation of sugarcane summarise the wealth of research addressing these challenges. Volume 1 reviews cultivation techniques and sustainability issues. Volume 2 reviews how the challenges facing sugarcane production can be addressed through developments in breeding as well as better management of pests and diseases. This volume, Volume 1, is devoted to key research on improving sugarcane production. The volume focuses on enhancing cultivation techniques such as good planting, irrigation and nutrient management, and addresses the latest methods of measuring and improving sustainability.

Part 1 Cultivation techniques

The focus of the first part of the volume is on summarising current best practices in sugarcane cultivation across the value chain, from planting through to post-harvest operations. Chapter 1 explains the development of sugarcane cultivation. Sugarcane is considered one of the most efficient plants on the planet given its capacity to transform solar energy into chemical energy with high carbon fixation rates. It has traditionally been exploited for sucrose production, but has also gained importance for energy and ethanol production from bagasse and molasses, two major co-products from sugar processing.

The chapter provides a concise history of sugarcane cultivation, as well as outlining the various different sugarcane species and providing a description of the sugarcane plant. The chapter describes current and historic practices in sugarcane breeding, as well as agronomic practices in sugarcane management and the process of sugarcane milling.

Chapter 2 builds on Chapter 1 by focussing on the role of crop modelling to support sustainable sugarcane cultivation. Crop simulation models can be used to support research and management of sustainable cultivation of sugarcane, and the chapter supplies case studies of strategic applications of this technology, including benchmarking of crop productivity and resource use and assessing environmental impacts of current operations, new developments and future scenarios. The chapter describes the use of crop modelling support for operational management, including irrigation scheduling and yield forecasting. The chapter discusses strengths and weaknesses of different modelling approaches and their relevance for a variety of applications, as well as looking ahead to opportunities for integrating crop modelling with new crop monitoring technologies and improved weather forecasts

Expanding in detail on one possible approach to achieving sustainable sugarcane cultivation, Chapter 3 focusses specifically on the Sustainable Sugarcane Initiative (SSI). This technique has been trialled in India to reduce the ecological footprint of sugarcane cultivation whilst at the same time expanding land area under cultivation for sugarcane in order to meet increasing global demand for sugar. The SSI is designed to meet this

challenge, and Chapter 3 describes the origins of SSI and its basic principles. Understanding tillering architecture is key to SSI, and the chapter gives a detailed account of SSI field trials in India, as well as outlining the expansion of SSI to Africa and Latin America

Complementing Chapter 3, Chapter 4 focusses on good planting and other cultivation practices in sugarcane cultivation. The chapter explains how plant crop establishment provides an opportunity to ensure that best management practices (BMPs) are identified and implemented or continued on-farm. This chapter concentrates on a philosophy of BMP associated with sugarcane farming systems and explores how this philosophy enables good decision-making when crop establishment practices and activities are being considered and implemented by a grower. The chapter addresses the need for best practice crop establishment, planning for sugarcane crop cycles, implementation of crop establishment plans, residue management, rectification and soil amelioration activities, fallow and sugarcane planting strategies, and sugarcane cultivation practices including weed-control and irrigation.

Chapter 5 follows on from Chapter 4's theme of good planting practices to examine the challenge of improving soil management in sugarcane cultivation. Chapter 5 identifies the most important soil management practices for sugarcane cultivation and provides information on the practices used by important cane producing countries in the world. The chapter focuses on field management of soil for optimum sugarcane production, and covers such areas as water management, tillage, minimizing soil compaction, cover cropping, soil fertility, and crop residue management.

Chapter 6's theme of improving nutrient management in sugarcane cultivation builds on the preceding chapter's focus on soil management. Chapter 6 shows that a nutrient management strategy which relies on the total replacement of all nutrients in the biomass is not sustainable from an economic or environmental point of view. The chapter reviews more sustainable strategies for nutrient management in sugarcane cultivation. It begins by discussing the benefits of crop rotation, green manure and trash retention, before offering a detailed consideration of cane fertilization with nitrogen and other macronutrients, micronutrients and silicon. The chapter considers the potential uses of cane processing residues and assesses foliar nutrition diagnosis as a tool to evaluate the nutritional status of a crop.

Chapter 7 addresses another important field in the area of sustainable sugarcane production, notably the advances that have been made in irrigation of sugarcane in order to optimise water supply. As the climate changes, irrigation presents a major challenge in improving sugar cane crop performance and extending cultivated areas. The chapter describes the water requirements of sugarcane and current irrigation practices, as well as suggesting ways of adjusting and optimising sugarcane irrigation that can make it more sustainable, including the use of decision-making tools. The chapter is supported by detailed case studies of irrigation practices in Réunion Island (France) and Senegal as examples of contrasting environments.

Chapter 8 continues the theme of water use in sugarcane cultivation by addressing best management practices for maintaining water quality. The chapter draws on evidence from two well-established long-term best management practice programs providing a measure of water quality management. These are the BMP program (SmartCane) adopted by the Australian Sugar Industry, and the BMP program adapted by growers in the Everglades Agricultural Area in South Florida, USA. The chapter addresses the importance of understanding nitrogen cycling to maintaining water quality and thereby sustainability of sugarcane production.

Chapter 9 builds on the themes of previous chapters, which focus on the deployment of technology in sugarcane cultivation, by addressing the issue of precision agriculture in sugarcane production through a detailed case study from the Burdekin region of Australia. Precision agriculture involves the use of spatial information about crop performance and the biophysical characteristics of the production system at the field and sub-field scales, in order to optimize agronomic management decisions. The chapter uses a 26.7 ha field in the Burdekin sugarcane growing region of Australia to illustrate how precision agriculture technologies might be used to enhance sugarcane production. In this case, precision agriculture achieved a saving of A$330/ha in gypsum application costs through the use of variable rate application.

The chapter examines potential future prospects for the further development of sugarcane precision agriculture, including improved variable rate fertilizer equipment, on-the-go sensing of commercial cane sugar at harvest, detection and spot spraying of weeds. Detrimental environmental impacts from sugarcane production can be reduced by recognizing that, under uniform management, areas that are low yielding have low efficiencies of fertilizer use and so may have increased risk of nutrient loss off-site. Precision agriculture technologies explored in the chapter include yield monitoring and mapping techniques, remote and proximal sensing, high resolution soil survey and digital elevation modeling, and data analysis and integration.

Chapter 10 moves the focus of the book to the process of sugarcane harvesting, examining advances in the harvesting and transportation of sugarcane. The chapter describes preparation of sugarcane for harvesting, including the importance of pre-harvest ripening. It outlines the available harvesting options, including infield loading and transport. It considers two harvesting systems, manual and mechanical harvesting, each of which is affected by whether the crop is burnt or not burnt immediately before harvest. The chapter explores the advantages and disadvantages of each method of harvesting and transportation.

Looking beyond the conventional use of sugarcane as a source of sugar for human consumption, Chapter 11 is focussed on the challenge of cultivating sugarcane for use in new and emerging bioenergy applications, and the key issues associated with this effort. The high biomass and sucrose accumulation in the stem of the sugarcane plant render it a favorable feedstock for bioenergy production. Chapter 11 reviews the challenge of competing with food crops when cultivating sugarcane for bioenergy, as well as loss of biodiversity, potential increase in pest problems, water, air and soil pollution, yield maximization, susceptibility to drought and cold, and the issues posed by sugarcane's complex genome. The chapter shows how these issues are being addressed through research into genetic improvement, improved understanding of agronomics and improved pest management practices. Case studies from Brazil and the US offer a brief overview of sugarcane development for energy production in these two countries.

Part 2 Quality and sustainability

The focus of the second part of the volume is on ways of measuring the environmental impact of sugarcane cultivation, as well as on the ways in which smallholders can be effectively supported. Chapter 12 concentrates on the challenges of analysing the processing quality of sugarcane. Knowledge about sugarcane's compositional traits is becoming increasingly important as industries attempt to achieve sustainability in sugar

production and to produce by-products from sugarcane. Chapter 12 discusses the composition of the whole sugarcane plant, sugarcane juice and sugarcane fiber and bagasse. It reviews how composition varies among and within species of sugarcane, and among commercial varieties. Finally, the chapter covers sucrose extraction methods, sustainable production and harvesting practices, quality parameters and grower payment schemes.

Chapter 13 complements the preceding chapter by addressing an over-arching issue of great importance to the present and future of sugarcane cultivation, the challenge of predicting the effect of climate change on the cultivation of this crop. It is acknowledged that sugarcane can be a source of ethanol and biomass for energy generation as part of a climate change mitigation policy. However, sugarcane is also an important crop from a food security perspective, with almost 75% of the world´s sugar coming from sugarcane plantations. Chapter 13 reviews the potential impacts of climate change on sugarcane crops, focusing on the likely effects of changes in air temperature and CO_2 concentration. The effects of changes in rainfall patterns and water stress are also discussed. The chapter uses experimental and process-based dynamic crop growth models (PBCM) to demonstrate the potential climate change impacts on the crop for the main sugarcane producing countries.

Chapter 14 continues and expands the themes of Chapter 13 by examining efforts to mitigate the impact of environmental, social and economic issues on the cultivation sugarcane, in order to achieve sustainability. The chapter focuses on the impact of agrochemical use and greenhouse gas (GHG) emissions and how these may be mitigated. The chapter identifies the persistent effects of agrochemical practices as well as strategies aimed at mitigating their impact. It examines the sources of greenhouse gas emissions and some of the challenges associated with implementation of the practices required to mitigate their effects. The chapter outlines arguments associated with the economic value of the practices that underpin adherence to improved environmental management.

Chapter 14 includes a detailed case study from South Africa describing SUSFARMS®, an expansive learning approach to enhance adoption of a sound environmental management system. The chapter considers the imperative of balancing the environmental impact of sugar cane cultivation with the clear economic need for sustainable growing of sugarcane, concentrating ultimately on the potential of sustainable production by small-scale growers.

The final chapter in the volume, Chapter 15, examines the role of sugarcane as a renewable resource for a sustainable future. The chapter highlights sugarcane's significance as not only the main source of sucrose but also the world's most important energy crop. Sugarcane has an important role to play in the transition to global sustainability, owing to its high productivity, its concentration in developing and emerging economies and the wide array of commercial products that it can provide. Chapter 15 describes the diversification of sugarcane production systems into multiple energy and non-energy products, improving economic competitiveness and environmental sustainability. Improved sugarcane production can contribute to greater social equality where good governance and inclusive institutions are designed and implemented, and a case study from Brazil is included to explore these possibilities. The chapter focuses on sustainability assessment, including the entire supply chain from cultivation through end use, describing the development of bio-refineries using sugarcane as feedstock and examining the ways in which efficient and effective use of sugarcane resources supports sustainable development pathways.

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