BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Achieving sustainable cultivation of maize

Volume 2: Cultivation techniques, pest and disease control

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burleigh dodds
SCIENCE PUBLISHING

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Introduction

Maize is one of the most widely-grown crops in the world, both for food and livestock feed, biofuels and other uses. Cultivated on 184 million hectares globally, maize is cultivated in 160 countries throughout the continents of America, Europe, Oceania, Africa, and Asia. Maize is fundamental to global food and economic security, providing up to 30% of total calorie intake in some developing countries. It has been estimated that maize yields need to increase by 60% by 2050 in the context of increasing competition for land, water, energy and labour. Maize production is currently held back by factors such as: lack of available improved cultivars or failure to take up new improved varieties, inadequate crop management and storage, poor soil quality, the impact of pests and diseases, and more extreme weather related to climate change. Research needs to focus on supporting more productive, sustainable and nutritionally-valuable maize cultivation, particularly for smallholders in the developing world.

The two volumes of *Achieving sustainable cultivation of maize* summarise key research addressing these challenges. This volume looks at ways of improving maize cultivation as well as the management of pests and diseases. Volume 1 focuses on breeding, improving nutritional quality and ways of supporting smallholders.

Part 1 Maize cultivation techniques

Crop models both help to identify opportunities for yield improvement and to predict the effects of factors such as changing weather patterns. Chapter 1 reviews the principles and development of existing crop models for maize. It then focuses on the problem of drought stress which is likely to increase in range and severity with climate change. Robust crop models are needed to predict likely drought impacts on maize production. The chapter reviews current research on predicting plant responses under drought and heat stress, particularly biomass production and grain yield formation. These models provide the foundation for assessing what interventions, whether in terms of breeding or cultivation practices, may be needed to maintain yields and grain quality.

To be sustainable maize production must meet a number of objectives. These range from producing a good quality product, optimising yields and ensuring a livelihood for the farmer to protecting the natural resource base in such areas as soil health and the broader environment. Good agricultural practices (GAP) allow farmers to achieve these objectives. However, the gap between potential and actual yields can make it complex to set realistic and achievable yield goals. In addition implementation of GAP will vary according to the demands of different production conditions. Chapter 2 addresses ways setting targets, establishing the right mix of cultivation practices and measuring performance. It includes case studies of practical GAP implementation in three different situations: irrigated production in Nebraska, smallholder rainfed production in the semi-arid Central Rift Valley of Ethiopia (CRVE), and rainfed maize in the Pampas of Argentina.

New maize varieties will not be effective if they are not properly disseminated and adopted by local farmers. Chapter 3 reviews the development and effectiveness of the collaborative drought and low nitrogen maize breeding program initiated by the International Maize and Wheat Improvement Centre (CIMMYT) to increase yields

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in low input and drought prone environments in southern Africa. Reflecting themes discussed in Volume 1, it describes initiatives such as CIMMYT's use of mother-baby trial (MBTs), an innovative farmer participatory evaluation scheme that evaluates farmer responses to new maize varieties in their own environmental conditions. This approach has accelerated the development and dissemination of new stress tolerant and high yielding open pollinated varieties (OPVs) and hybrids in southern Africa. The chapter also highlights the development and selection of maize germplasm resistant to a range of biotic and abiotic stresses, and the role of the seed industry in disseminating improved maize germplasm.

Maize is the most important staple food crop for over 300 million people in Sub-Saharan Africa but poor management practices and problems related to climate and soil quality mean that yields regularly fall below what is needed to feed the population. Chapter 3 begins by describing the effect on maize yields of poor soil fertility, drought and weeds (especially Striga hermonthica). Building in particular on Chapter 2, it then identifies good agricultural practices (GAP) to address these problems. These techniques include targeted nutrient management to improve soil health and techniques for weed management. The chapter also examines ways of dealing with the challenge of drought, including improved irrigation methods and development of drought-resistant maize varieties.

Chapter 5 builds on Chapter 4 by focussing on the role of zero-till cultivation of maize. This technique aims to reduce erosion, improve soil structure and nutrient composition, decrease costs, and improve long-term sustainability of maize cultivation. However, it is important to understand what factors determine whether the technique is effective or not. The chapter reviews current research on the effects of zero till cultivation in such areas as reduced soil erosion and nutrient losses, water infiltration and soil organic matter. This chapter discusses suggestions for best management of zero-till maize systems.

Zero-till cultivation is one element in a broader set of practices known as 'conservation agriculture' (CA). CA emphasises practices designed to improve soil health such as: zero or reduced tillage; retention of adequate levels of crop residues and soil surface cover to improve water productivity and to enhance soil physical, chemical and biological properties; and use of crop rotations to help control weeds and pests, improve soil health and provide more diverse sources of income for farmers. Based on long-term experimental sites managed by CIMMYT, Chapter 6 provides an authoritative review of the effectiveness of CA in such areas as physical soil quality (including reducing erosion), soil chemical and biological quality, and weed management. As it shows, forty years of research show that conservation agriculture has proved the better choice in providing continuously higher and more stable yields for both wheat and maize when compared to traditional practices in rainfed conditions. The chapter discusses the future potential of CA in maize cultivation and, specifically, its further development in Latin America.

As Chapter 7 points out, information and communication technologies are transforming the way maize is cultivated around the world by providing farmers with a suite of novel tools and techniques for improving crop production, enhancing input use efficiency, and increasing profitability while achieving environmental sustainability. Chapter 7 provides an overview of the current state of precision maize cultivation techniques at different stages of maize cultivation. A section on pre-planting assesses current knowledge on the spatial variability of soil properties and how it influences precision maize cultivation techniques. Subsequent sections address planting and the current state of variable-rate seeding, nutrition and various approaches for site-specific fertilizer management. The chapter also reviews developments in precision irrigation, different aspects of precision pest control

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and weed management, as well as the opportunities enabled by digital yield maps and big data management.

Sustainable cultivation requires more efficient resource use, including in the use of fertilisers. Chapter 8 looks at the various ways of improving nutrient management in maize cultivation. It includes a range of case studies from South Asia, Sub-Saharan Africa, Latin America as well as the use of the Nutrient Expert® tool in China. As an example, in the case of Sub-Saharan Africa, the chapter reviews ways of targeting fertilisers according to different soil conditions, establishing optimum nitrogen application rates and more effective timing of nitrogen application (depending on prevailing rainfall) as well as more targeted, site-specific fertilizer application. It shows for example that, when combined with mineral nitrogen fertilizers, manure resulted in better crop yields than fertilizer treatments alone. The chapter also demonstrates the success of more flexible systems of fertilization, in which optimum rates of P, K and S fertilizers are applied based on yield potential in an average rainfall season, while N is applied as a series of split applications, which are adjusted according to the evolving rainfall pattern in any one season.

Modern agriculture has led to a simplification of maize-based cropping systems and the extensive practice of monoculture maize. This has led to problems such as yield reduction and soil quality degradation. Meanwhile, as pointed out in Chapter 8, the overuse of inorganic fertilizer to increase yields comes with a high environmental cost. As suggested in Chapter 6, maize grown in rotation with grain or forage legume crops often yields more and requires less application of synthetic chemicals (fertilizers, pesticides, herbicides, etc.) than continuous monoculture maize. Rotations in tandem with the application of farmyard or dairy manure or other organic wastes has proved an environmentally-friendly strategy for sustainable agriculture development. Chapter 9 summarizes recent research on yield enhancement in maize-based rotation systems, as well as the impact of crop rotation on soil quality, fertility and nutrient use efficiency.

Chapter 10 reviews the existing evidence on the productivity and resource use efficiency of maize–legume intercropping systems compared to the use of single crops. Findings indicate that system productivity in intercropping systems is more resource-use efficient and productive, particularly in low-yielding environments and production systems where soil quality is poor and rainfall low. As the level of resource availability increases, the differences between intercropping and sole cropping are reduced, though intercropping still presents advantages over sole cropping in some cases.

Climate change, and the likelihood of hotter, drier conditions in many parts of the world, presents a particular threat to rainfed maize cultivation. Chapter 11 assesses the vulnerability of rainfed maize cultivation to changing conditions and the risk of rainfall variability. Supporting farmers to identify and manage risks and opportunities in these challenging conditions is essential. The chapter summarises recent research on risk management strategies for smallholder maize cropping. It concludes with a case study exploring practical options for the sustainable intensification of rainfed maize cropping in Mozambique.

Part 2 Maize pests, diseases and weeds

Maize yields in many countries are negatively affected by damage from insect pests. Chapter 13 describes the main pests of maize. These include below-ground pests such as

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various types of corn rootworm, above-ground pests such as the corn leaf aphid, as well as pests of stored maize products such as the larger grain borer. The chapter also includes a detailed case study of the European corn borer in the USA, assessing its life cycle and what this means for control using integrated pest management (IPM) techniques. Finally, the chapter assesses potential future directions for research in this area.

Plant-feeding, or plant-parasitic, nematodes are ubiquitous in soils that support plant growth. The effects of phytophagous nematodes are, however, notoriously difficult to test and measure, and depend upon many factors associated with the plant, its environment, and the nematodes themselves. This chapter begins with an introduction to soil and plant nematodes, covering their general characteristics, identification and an overview of our current knowledge of their effects on maize. Subsequent sections review various types of nematodes, with particular focus on those which are highly likely to cause yield losses and other damage to maize crops such as lesion, root-knot and vermiform nematodes.

Rodents cause significant damage at the sowing, seedling and maturity stage of maize. Rodent management programs in regions such as Sub-Saharan Africa have traditionally been reactive and most suited to managing low-density local rodent populations. More effective rodent management requires a more proactive and integrated approach. Chapter 15 describes the range of cultural, chemical and biological methods of control that make up an integrated rodent management programme. It also looks at improvements in surveillance and early warning systems.

Emerging plant diseases (EPDs) can cause significant losses to maize and other crops. Chapter 16 reviews research on factors influencing the origins and spread of EPDs affecting maize. Effective control of EPDs relies on rapid detection, accurate diagnosis, as well as speedy deployment of preventive and containment measures to prevent the spread of disease. The efficiency of a response also depends on networking and collaboration among all the stakeholders, including intergovernmental and nongovernmental organizations and specialized agencies in developed and developing countries. The chapter reviews strategies for mitigating risks from emerging maize diseases, components of an effective rapid response system and strategies for managing maize disease outbreaks. These include effective models to predict the likely spread of disease, quarantine procedures, effective seed systems, integrated disease management and pre-emptive breeding measures. The chapter includes a case study of how procedures worked in practice with the emergence of maize lethal necrosis (MLN) in eastern Africa, reviewing how effective various agencies were in responding to the MLN outbreak and minimizing its impact.

Maize is subject to pre- and post-harvest contamination with aflatoxins, which are acutely toxic and carcinogenic compounds. This chapter describes in detail mechanisms of aflatoxin contamination in maize. It also reviews the current strategies employed for aflatoxin control and the challenges associated with them, including pre- and post-harvest methods of control and prevention. The chapter also addresses the detoxification of aflatoxin-affected maize as well as suggesting lines of future research in this area.

Weeds are one of the major constraints on maize productivity. Chapter 18 discusses the impact of weeds on maize cultivation and methods of control. It focuses on integrated weed management (IWM) techniques which reduce the need for herbicides. IWM techniques include methods of cultural control such as: land preparation, choice of cultivars, planting schemes and methods of cultivation. They also include cropping systems such as rotations, intercropping and cover crops, as well as physical methods of control. The development of herbicide-tolerant maize cultivars and image-based site specific herbicide applications are expected to contribute significantly in improving weed management in maize.

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Chapter 18 is complemented by Chapter 19 which reviews the types of maize cropping systems used to grow maize under temperate conditions, with a particular focus on the situation in the US and Europe. After reviewing weed flora in these regions, it discusses current weed management systems and the herbicide resistance issues that have developed through the continuous use of herbicides. Echoing Chapter 18, it emphasises the importance of integrated weed management (IWM) techniques in achieving more sustainable maize production. The chapter concludes with IWM case studies in three European maize production regions.

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