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Achieving sustainable cultivation of potatoes

Volume 2: Production, storage and crop protection

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Preface

Research into the production, storage and utilisation of the potato crop is increasing steadily. This is, perhaps, unsurprising given that it is the fourth most important staple food in the world after wheat, maize and rice and that the area and quantity of potatoes being grown worldwide continues to increase. There is no aspect of the potato crop and its cultivation that is not under investigation somewhere, reflecting the fact that as a vegetatively produced crop it presents more challenges in production than grain crops.

What is changing dramatically with the potato crop are the demographics of consumption. A cursory glance at FAO statistics on the crop will see that, in general, in developed countries potato production has peaked and is often declining, whereas in developing countries it is rapidly increasing, with Asia, particularly China, and Africa leading the charge. Of course, potatoes are still important in developed countries but the choice of food options is much greater and consumers demand better quality and more diverse options. The focus in developing countries remains primarily yield, and this often relates to finding solutions to basic production issues such as appropriate cultivars, provision of healthy seed, water and nutrient to feed the crop and basic crop protection. By contrast, in developed countries where often, high yield is relatively straightforward to achieve, more focus in on quality, added value and consumer safety.

Traditionally, scientific research into potatoes has been carried out in largely publically-funded institutes around the world. Researchers in these institutes have a desire to publish refereed papers as the end point of their research. These papers are the life-blood of progress as they provide open access of validated results for agronomists and economists to turn into practice. The majority of research will continue to be carried out by institutes, but there is an increasing proportion of research being carried out by industry where the publication of research is secondary to profit from developing a patented product. An example of this is the development of GM cultivars.

In reviewing potato research publications, it becomes apparent that, to date, the majority have emanated from institutes in developed countries where long term research programmes have been established. This is not to say that excellent research does not take place elsewhere. For example, the International Potato Centre (CIP) in Peru has an enviable record in scientific research. However, as developing countries rely more heavily on the potato crop and they increase in wealth it can be anticipated that a greater proportion of potato research will be published from institutes in these countries.

The focus of research in institutes remains addressing challenges to the potato crop and developing new ideas and initiatives. Obviously, the focus for research will vary from country to country and region to region and often reflects local emerging challenges. One example of an emerging challenge is the relatively recent occurrence of Zebra chip disease in a few major areas of production. Naturally, this problem has been intensively studied where it has become established but neighbouring countries or countries trading with them have had to take the disease seriously in order to limit its spread.

In developed countries, there has been an increasing focus on quality aspects and this has resulted in a continuing requirement for under-pinning research. The move to understanding processes at the molecular level, for example using information from DNA sequencing of the potato, has expanded rapidly. These fundamental areas of study will ultimately lead to many diverse improvements in production, storage and

utilisation especially through the development of new or improved cultivars with specific traits. Naturally, expectations for rapid progress are high and greater funding has been moved into molecular and genetic research. To an extent, this has been carried out at the expense of more applied research. Sustained applied research is equally important and governments need to ensure that institutes sustain a balanced portfolio of strategic and applied research.

When presenting the complexities of the potato to a lay person, it is often the case that they cannot understand why so much research is required. They may have the image of crop production simply being the task of planting a tuber into the soil and waiting for it to grow. These two volumes of *Achieving sustainable cultivation of potatoes* bear witness to the level of complexity production, storage and utilisation has reached. That there are two volumes and such a wide range of topics covered should convince those with a simplistic view that potatoes are a technologically advanced crop.

There was a time when one person could be familiar with most aspects of potato research. One such person was W. G. Burton, who published the first edition of his *Magnum Opus* 'The Potato' in 1966. This was one of the first publications to present a comprehensive overview of potato research in a single volume and is a work of immense stature. It reflects the breadth of understanding he had for the crop. It might be suggested that no one individual today could retain such a breadth of expertise.

Yet there remains a need, every now and again, to assess the state of play in potato research. These two volumes attempt to review the progress made in the last 10 years or so. Not every aspect of potatoes is covered but these volumes follow a tradition of bringing the latest research into an accessible publication. Unlike W. G. Burton's book, more recent research review publications have been written by scientists expert in one aspect of potatoes and edited by more generalist researchers. Thus these volumes follow the legacy of Burton (1966), Harris (1978) and Vreugdenhill (2007) amongst others.

Stuart Wale

References

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Introduction

Potatoes are the fourth most important food crop in the world and the most important root crop. Their nutritional value, and the fact that they can be grown with relatively few inputs in a wide range of environments, makes them an important food security crop. However, yields in developing countries are held back by factors such as poor cultivation practices, the impact of pests and diseases and limited breeding to identify climatically adapted cultivars. In more intensive systems, crops need to become more 'climate smart' to minimise environmental impact and adapt to climate change. These challenges are addressed in the two volumes of *Achieving sustainable cultivation of potatoes*:

- Volume 1 Breeding improved varieties
- Volume 2 Production, storage and crop protection

Volume 2 looks at key recent research on improving cultivation techniques at each stage in the value chain for potato production, from yield modelling to post-harvest storage. The volume also offers a detailed review of the main fungal, bacterial and viral diseases affecting potatoes.

Part 1 Potato production and storage

The themes of chapters in the first part of the volume range from modelling yields to nutrient and irrigation management, as well as post-harvest storage. The subject of Chapter 1 is modelling potato growth. The development of mechanistic models for predicting growth of various crops (including potatoes) has continued for several decades, and new applications of such models are increasingly becoming available. Despite the benefits of this development, it may be difficult for the user to decide which models are suitable for a specific purpose (such as decision making in potato production). This chapter provides insights intended to help the potential user to better understand the benefits and limitations of various types of models. The chapter first presents some ideas of the general principles of mechanistic modelling and potential applications of crop models. It then briefly describes the main physiological processes of potato growth and how they have been handled in mechanistic models. Finally, the chapter provides examples of the recent applications of potato models and discusses the future use of the models for new applications, particularly in precision farming.

Chapter 2 offers an overview of ways of improving more sustainable potato cultivation. This chapter does so by exploring the adoption of conservation agriculture and other techniques by potato growers in the Indo-Gangetic plains. Focusing on the goals of optimizing soil health and achieving vigorous early crop growth, it reviews best practice in soil management, seed bed preparation and planting, and cultivation techniques, including irrigation. The chapter then moves on to consider the contribution of green manures and cover crops to potato nutrient management, as well as the impact of mechanisation.

Moving to a specific aspect of potato cultivation, Chapter 3 focuses on improving nutrient management. Potatoes require a significant number of mineral nutrients and this chapter describes management practices that maximise crop production whilst minimising

nutrient losses to the environment. It first describes the development of the crop and requirements for macronutrients (nitrogen, phosphorus, potassium, sulphur, magnesium, calcium) and micronutrients (chlorine, boron, iron, zinc, manganese, copper, nickel, molybdenum), and current agronomic practices for delivering these nutrients. There follows an overview of recent developments in precision management of potato crop nutrition, underpinned by geospatially-referenced soil maps and application systems, which aim to optimise fertiliser inputs by addressing local heterogeneities in soil conditions and varying inputs across a cultivated area. Finally, the chapter describes how agronomic strategies can be complemented by breeding cultivars with more efficient acquisition of mineral nutrients. These breeding programmes focus on root characteristics, and better physiological utilisation of nutrients for tuber yields, as well as on canopy architecture and nutrient or biomass partitioning within the plant.

Complementing the previous chapter's concentration on nutrients, Chapter 4 addresses advances in irrigation technology and management in potato cultivation, drawing on examples mainly from the UK. Irrigation is an essential component of potato production for many farmers, serving to maximise yields and meet quality assurance targets for retailers and consumers. In recent years, rising financial and environmental costs have led to increasing attention given to improving on-farm irrigation efficiency and water productivity, or 'more crop per drop'. The chapter focuses on recent advances in both in-field water management (notably irrigation scheduling) and application equipment, including the challenges in implementing precision irrigation technologies, to improve productivity and reduce water demands. Whilst the chapter reports experiences from the UK, the issues raised are equally applicable to other environments where water resources for agriculture are under scrutiny and potatoes are an important commodity crop.

Chapter 5 shifts the focus to organic potato cultivation. Organic potato cultivation requires a whole-system approach, with a particular focus on rotation design. Producing organic potatoes relies strongly on indirect, preventive and long-term strategic measures both for plant nutrition and plant protection. The chapter examines all aspects of the process of cultivating organic potatoes, including breeding, seed potatoes, rotation and diversification, planting, tillage, weed control, nutrient management, soil fertility and irrigation. The chapter also describes the main diseases and pests of potatoes and organic methods of their control.

The theme of Chapter 6 is post-harvest storage of potatoes. Storage is a major component of the field-to-fork cycle and a point in the cycle where major crop loss can occur. Good storage is essential to maintain supply and quality of both ware and seed potatoes. The chapter reviews the mechanisms underlying potato spoilage and discusses key techniques for storing potatoes to maintain quality and shelf life. Pathological and physiological factors both impact on quality and can affect the proportion of a crop that is marketed. These are discussed in relation to current storage practices, highlighting control methods.

Moving from storage to processing of potatoes, Chapter 7 examines acrylamide formation in fried potato products and ways to mitigate its occurrence. Acrylamide is formed in potato products during cooking in industrial processing, retail, catering and home preparation. The chapter summarizes the research to date on acrylamide levels, mechanisms of formation in tubers, assessment of acrylamide intake and health risks, regulatory status and possible mitigation strategies from farm to fork in the growing and processing potatoes for fried potato products.

Part 2 Diseases and pests

The chapters in the second part of the volume review advances in understanding and managing fungal, bacterial and viral diseases as well as the management of pests and weeds. Chapter 8 addresses the subject of fungal diseases affecting potato storage. Fungal and oomycete pathogens responsible for causing potato storage diseases are both numerous and ubiquitous wherever potatoes are grown. Such pathogens can result in losses of up to 10% during storage, with additional losses caused in the field in subsequent growing seasons when planting affected stored seed crops. Previous research has tended to focus on individual diseases and their management in isolation but, given the variety of possible pathogens, there is a growing need to understand common issues in potato storage diseases. The chapter considers the key issues in three stages: identifying the pathogens, understanding the epidemiology of the diseases, and managing the disease at different stages of development. The chapter includes a detailed case study of Fusarium dry rot in order to show how greater understanding of a disease can ensure its more effective management.

Chapter 9 moves on from fungal diseases to consider bacterial diseases affecting potatoes. Bacterial pathogens continue to pose a significant threat to potato production through in-field yield losses, storage rot and reduced marketability. *Ralstonia solanacearum* alone is estimated to cause $1 billion in losses worldwide. The chapter reviews current knowledge on the principal bacterial diseases of potato: ring rot (*Clavibacter michiganenis* subsp. *sepedonicus*), brown rot (*Ralstonia solanacearum*), blackleg (*Pectobacterium* and *Dickeya* spp.) and common scab (*Streptomyces* spp.), as well as the recently emerging pathogens, *Dickeya solani* and *Candidatus Liberibacter solanacearum*, causing blackleg and zebra chip respectively. The chapter reviews sustainable disease management strategies, and discusses how the development and increasing accessibility of molecular genetics enables new avenues of research.

Moving from bacterial to viral agents, Chapter 10 considers viruses affecting potatoes. The impact of viruses on potato production can be devastating in many areas worldwide. Breeding for agronomic and resistance traits, knowledge of virus species and their epidemiology, together with the development of accurate diagnostic methods have been essential for the development of integrated disease management strategies, and helped certification programmes worldwide to maintain high health standards. The chapter describes the current state of knowledge about viruses in potatoes and provides guidance on developing efficient control measures. It includes a detailed case study on the transmission and distribution of aphid-transmitted viruses in field conditions.

Complementing the focus of the previous three chapters on fungi, bacteria and viruses, Chapter 11 looks at non-infectious disorders affecting potatoes. A wide range of non-infectious disorders can affect potatoes, generally as a result of imbalances within the plant caused by environmental stresses. Such disorders make tubers unappealing to consumers, and therefore have significant economic consequences. However, non-infectious disorders are often poorly understood and characterized, limiting the extent to which they can be prevented and detected. The chapter describes a range of disorders of potato tubers, categorising them as external, superficial or internal disorders. In each case, a description of symptoms is given, followed by information about the causes of the disorder and ways of preventing and minimizing its symptoms.

The final two chapters of the volume move on to look at pests of potatoes, with Chapter 12 concentrating on the nature and impact of nematode pests. Potatoes are particularly susceptible to attack from nematodes, with around 70 species from 24 genera reported. Nematodes reduce the value of the harvested crop by affecting yield, tuber size and marketability or indirectly through the transmission of viruses. After reviewing what we know about the major nematode pests of potato, the chapter describes quarantine regulations affecting potatoes with regard to nematodes, before outlining techniques of nematode management.

The last chapter of the volume, Chapter 13, examines integrated potato insect pest management with a specific focus on the US Pacific Northwest. Over the past 20 years, potato pest management in the Pacific Northwest region of the USA has changed dramatically, with the emergence and resurgence of new insect pests. The chapter reviews the status of pest management in the region which aims to enable growers to maintain economically viable and sustainable potato production. The chapter describes the lifecycles and effects of the main arthropod pests in the region, including the beet leafhopper, the potato tuberworm and the most significant emerging pest, the potato psyllid, vector of zebra chip disease.

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