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Achieving sustainable cultivation of potatoes

Volume 1: Breeding improved varieties

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Introduction

Potatoes are one of the world's key food crops. 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 and the impact of pests and diseases, whilst more intensive systems 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 1 reviews general developments in breeding, research on improving particular traits, from stress resistance to nutritional quality, as well the challenges facing potato cultivation in particular regions. The volume reviews the latest research on understanding potato plant physiology and genetic variety. It discusses major advances in conventional, hybrid and marker-assisted breeding as well as their application in improved varieties, before focusing on ways of supporting smallholders in regions such as Africa and Latin America. Although a separate species, the book also includes selective coverage of research on sweet potato. The book is accompanied by a second volume which looks at ways of improving potato cultivation as well as advances in pest and disease management.

Part 1 Plant physiology and breeding

The first part of the volume assesses recent research on plant physiology and genetic diversity and their implications for conventional, hybrid and marker-assisted breeding. The subject of Chapter 1 is advances in understanding potato plant physiology and growth. The chapter looks at what we know about initial crop development and the factors affecting the subsequent development of the potato plant. The chapter examines in particular potato responses to water and heat stresses as well as nutrient availability and other factors.

Given its important implications for shelf-life, Chapter 2 reviews research on understanding ageing processes in seed potatoes. The physiological quality of seed tubers is very important for the performance of the crop grown from them, and interacts strongly with seed tuber size. Physiological quality consists of two components: dormancy and physiological age. The chapter reviews the conditions which influence both dormancy and physiological age, as well as the effects of seed quality on various aspects of crop performance. After considering seed tubers as the main propagules in potato production, the chapter deals with the quality characteristics of seed tubers, dormancy and physiological age, and the importance of seed quality as a yield-limiting and quality-determining factor. The chapter focuses on the importance of understanding dormancy, bud activation, initial sprout growth and apical dominance, as well as understanding aging in sprouts and mother tubers. The chapter provides an analysis of the dynamic development of physiological age and resulting crop performance, as well as assessing the causes of variation in physiological age and options for manipulation.

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The subject of Chapter 3 is the importance of ensuring the genetic diversity of potatoes. The opportunities for advances in the potato crop through genetics are significant, since potato has many needs for improvement, and related species with the traits required are available. The chapter discusses the special challenges, opportunities, and recent developments and accomplishments for potato genebanks in the areas of acquisition, classification, preservation, evaluation, and distribution of genetic stocks and information, as well as discussing key issues in access to genetic material.

Moving on the subject of breeding techniques, the subject of Chapter 4 is advances in conventional potato-breeding techniques. Potato is highly heterozygous and, in order to maintain productivity, improved potato varieties must be developed by inter-mating desired parental lines and selecting superior clones from the progeny. Since potato is vegetatively propagated, any selected genotype can be fixed with all its intra- and inter-locus interactions responsible for phenotypic expression, and multiplied for commercial cultivation if desired. Recent advances in molecular breeding provide opportunities for rapid genetic gain. Nevertheless, phenotypic selection remains the common practice in conventional potato breeding programmes. Nearly all new varieties of potato still emerge from a process free from use of molecular technologies. The chapter reviews the progress and advances made in phenotypic selection techniques of conventional potato breeding. The chapter describes the role of molecular approaches in improving phenotypic selection.

Complementing the preceding chapter's theme of potato breeding, Chapter 5 looks at hybrid potato breeding for improved varieties. Hybrid potato breeding promises to create new cultivars within a few years. This would facilitate the introgression of genes by marker assisted selection, and hybrid cultivars could then be made available as true seeds, free of soil-borne pathogens, quick to multiply and easy to transport and store. What were previously thought to be prohibiting factors for hybrid potato breeding have recently been overcome: nearly homozygous inbred lines have been created and the first experimental hybrids have been evaluated in the field. The chapter reviews the scientific basis for hybrid potato breeding and highlights the key features of a strategy for creating an inbred, line-based, hybrid potato crop that can be propagated through seed. The chapter discusses the recent progress made towards the development of useful hybrid varieties, and considers how the hybrid potato breeding technology platform will need to be adapted and optimized for different production systems.

Part 2 Improving particular traits

Building on Part 1, the second part of the book looks at ways developments in breeding have been used to improve particular traits. The focus of Chapter 6 is on advances in the development of potato varieties resistant to abiotic stress. Abiotic stresses such as drought, high or low temperature, salinity, submergence and nutrient deficiency can significantly impact potato yields. These suboptimal conditions restrict potato plant performance so that the plants do not reach their full genetic potential. The chapter examines different abiotic stress improvement targets in the potato as well as the variety of tools and techniques being developed and used for crop improvement for abiotic stresses. The chapter reviews technological advances to develop abiotic stress resistance in potatoes and tolerant varieties, especially through genetic engineering.

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Chapter 7 examines the challenge of developing early-maturing, stress-resistant potato varieties. The chapter describes the selection of germplasm and traits for breeding early maturing varieties of potato, exploring genetic aspects of earliness as a trait. The chapter looks at early tuber initiation, high dry matter partitioning efficiency and basic factors that need to be taken into account when breeding for earliness in potato. The chapter includes a detailed case study of developing an early-maturing, late blight-resistant Kufri Khyati potato variety for cultivation in India.

As a point of comparison, Chapter 8 deals with developing new sweet potato varieties with improved performance. Novel sweet potato varieties with improved traits are needed, especially for marginal lands and disease-prone regions. However, the high degree of heterozygosity, high male sterility, and self- and interspecific incompatibility of the sweet potato plant results in strong segregation of hybrid progenies. Molecular breeding provides a promising approach for the development of new varieties with value-added traits. The chapter reviews the development and application of genetic transformation and trait improvement to sweet potato, including the development of sweet potato plants which are resistant to disease and abiotic stress, and sweet potatoes with improved starch quality and higher anthocyanin content.

Chapter 9 begins by considering the nutritional properties and enhancement and bio-fortification of potatoes. There are a number of factors that make potatoes a logical focus for nutritional breeding efforts. As one of the world's staple foods, they have a key role to play in improving global food security, largely due to their nutritional value, storability, affordability and high yield. Recent years have also witnessed greatly increased consumer concern for healthy food choices, leading to high demand for an increase in the nutritional value of foods that have previously been subject to negative health publicity. The chapter reviews the nutritional composition of potatoes from diverse germplasm including vitamin C, B vitamins, potassium, carotenoids, phenylpropanoids and glycoalkaloids. In each case, the chapter discusses the feasibility and health benefits of increasing these nutrients through traditional and precision breeding programmes.

Chapter 10 deals with improving the breeding, cultivation and use of sweet potato in Africa. Sweet potato is a low input crop with significant potential for improving public health and nutrition and developing food security in Sub-Saharan Africa. The chapter examines the nutritional contribution made by OFSP (orange-fleshed sweet potato) in poor rural communities in Malawi, Ghana, Nigeria and Burkina Faso, sustainable breeding and seed systems and effective commercialisation and marketing to benefit the communities concerned. The chapter includes detailed case studies from Ghana and Malawi.

Part 3 Translating research into practice: improving cultivation in the developing world

The book's third section looks at ways of supporting smallholders in regions such as Asia, Africa and Latin America to improve potato cultivation. Chapter 11 offers an overview of potato production and breeding in China. The chapter outlines current potato production and consumption, identifying key trends and challenges. The chapter explores challenges associated with germplasm material, breeding objectives and development of new varieties, and the types of new variety available. The chapter considers the possibility of virus-free seed potato production.

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The subject of Chapter 12 is the challenge of improving potato cultivation to promote food self-sufficiency in Africa. Demand for potato in sub-Saharan Africa is growing, but the projected growth in demand is not matched by the projected growth rate in local potato production. An interplay of factors ensures the production gains achieved are small and slow. The chapter reviews the current state of potato production in Africa, and the challenges it faces. The chapter describes the development and promotion of suitable potato varieties, considers crop improvement initiatives and programs, and emphasises the potential of potato to contribute to food security and poverty reduction.

The volume's final chapter, Chapter 13, addresses the importance of supporting smallholder women farmers in potato cultivation. It is clear that women farmers have a vital role to play in shaping and maximising this growth, safeguarding potatoes as a primary food security crop. The chapter offers a summary of the current state of potato cultivation and the role of women, with a focus on sub-Saharan Africa. The chapter highlights the enormous potential of women farmers in promoting the broader goals of development and food security in these areas, before examining some of the challenges women face in making their voices count. The chapter presents different strategies for supporting women smallholders, with a particular emphasis on ensuring that women benefit from agricultural training and have the opportunity to apply their knowledge and resources.

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