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Achieving sustainable cultivation of grain legumes

Volume 2: Improving cultivation of particular grain legumes

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Foreword

The world continues to face serious challenges of hunger and malnutrition as well as the challenges of increasing food production in a sustainable way that protects the environment and maintains the productivity of agricultural land. According to the FAO, despite all the efforts to address these challenges over many years, about 795 million people of the 7.3 billion people in the world, or one in nine, suffered from chronic undernourishment in 2014–2016. Despite their vital importance to address these global challenges, pulses have not received sufficient world attention for the potential role they can play. Pulses are at least 3 to 4 times richer in plant-based protein compared to major cereals crops such as rice and wheat. They have a complementary amino acid profile with cereals and make a balanced diet when combined with cereals. This is particularly important for the low-income strata of the population. They are also high in micro-nutrients, especially iron and zinc, which address the problem of hidden hunger and anemia. Pulses are also high in dietary fiber and a good source of carbohydrates which makes them a great functional food.

In addition to their unique nutritional qualities, pulses, as leguminous plants, fix atmospheric nitrogen which enhances soil fertility and maintains soil productivity, protecting the environment. They have a relatively low carbon footprint compared to other crops since they do not require chemical nitrogen fertilizer. Including pulses in crop rotations reduces the overall N fertilizer requirement of crop production systems which has great benefits to the subsequent crops in the rotation. This makes them important climate change crops. Pulses are certainly the best crops to solve the soil problems caused by the cereals monoculture that many developing countries follow due to the subsidies for cereals.

Only very recently the world community recognized the importance of pulses through the declaration of 2016 as the International Year of Pulses (IYP 2016). This was announced by the United Nations General Assembly upon the recommendation of FAO General Conference. Although the recognition was belated, it has been an excellent opportunity 'to raise public awareness of the nutritional benefits of pulses as part of sustainable food production aimed towards food security and nutrition'. The IYP 2016 was successful in achieving its objectives considering the many activities held throughout the world, as was well documented by The IYP 2016 Legacy developed by FAO with other stakeholders on pulses as 'nutritious seeds for sustainable future'.

However, pulses still face major challenges that require immediate attention so that they can play their potential role to help achieve food and nutritional security as well as sustainable agricultural production systems. The areas that require immediate attention include the following:

- Pulses should be considered as major crops and not as secondary crops mostly grown under rainfed marginal conditions. Thus, they deserve much more investment in both research and development (R & D) which are currently negligible compared to the R & D investment in cereals.
- More research efforts should focus on ensuring high yield potential by utilizing a wider range of genetic diversity to mine desirable genes from both conserved land races and wild relatives.
- More work needs to be done on yield instability through breeding for tolerance and durable resistance to a range of abiotic and biotic stresses.

- More attention needs to be paid to emerging new constraints and stresses that are caused by climate change, including excessive drought and heat as well as emerging diseases and insect pests.
- Overcoming inappropriate policies favouring cereal production at the expense of pulses as a result of subsidies. This could involve either lifting subsidies on cereals or providing similar subsidies to pulses as India rightly did recently.
- Last but not least, overcoming the limited access of farmers to high quality seed from improved varieties and other important inputs for high pulses productivity.

The two volumes of *Achieving sustainable cultivation of grain legumes*, the first on advances in breeding and cultivation and the second on improving cultivation of particular grain legumes, are very timely. They bring more visibility to these important crops as well as updated knowledge on both the science and practical advances in cultivation addressing the challenges facing specific pulses so that they can play their role in achieving food and nutritional security as well as sustainable agricultural production.

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Introduction

Grain legumes are widely cultivated, particularly for their dry seeds (known as pulses). The FAO defines pulses as crop plant members of the *Leguminosae* family (commonly known as the pea family) that produce edible seeds. In this definition, only legumes harvested for dry grain are classified as pulses, excluding species such as soybean and groundnut. However, broader definitions of grain legumes include groundnut and soybean as well as common bean and lentils which are grown globally. Other more regionally-specific types of pulses include cowpea, faba beans and pigeonpea.

Grain legumes are important in the developing world for a number of reasons. They are a rich source of protein and fibre, minerals and vitamins. In addition, their rapid growth and ability to fix nitrogen and improve soil health makes them a key rotation crop in the sustainable intensification and diversification of smallholder farming. This makes grain legumes a key food security crop. However, yields in developing countries are low as a result of such factors as the need for improved varieties of seed, poor seed distribution, the impact of pests and diseases, as well as vulnerability to poor soils, drought and other effects of climate change. There is now a rich body of research addressing these challenges.

The challenges facing grain legumes are addressed in the two volumes of *Achieving sustainable cultivation of grain legumes*:

- Volume 1 Advances in breeding and cultivation techniques
- Volume 2 Improving cultivation of particular grain legumes

This volume reviews key research on particular types of grain legumes with chapters on developing improved varieties as well as improvements in cultivation techniques. Part 1 covers common beans, lentils, soybeans and groundnuts. Part 2 discusses cowpea, faba beans and pigeonpea.

Part 1 Cultivation of common beans, lentils, soybeans and groundnuts

There is a long history of genetic improvement of the common bean. Chapter 1 describes breeding programs focusing on a wide range of biotic and abiotic production constraints, traits for local adaptation and consumer quality, with yield being the overriding challenge for most bean breeding programs. The chapter assesses the wide range of breeding procedures used to improve bean yields, from ideotype to molecular breeding. It discusses the impact of these techniques on yield gains and future trends in genomic analysis research on yield improvement.

Chapter 2 looks at the origin, domestication and economic importance of common bean, including world production trends. It also assesses production constraints, such as soil fertility and acidity, pests and diseases, drought and heat stresses. It goes on to describe ways of addressing these constraints through cropping systems, integrated pest management, and management of diseases such as angular leaf spot (ALS), anthracnose, common bacterial blight and halo blight. Water and nutrient management, including phosphorus and nitrogen, are discussed, as well as sections on liming and foliar fertilization.

Lentil is a popular pulse consumed primarily in Asia. It has a high protein content and also contains high amounts of macro- and micro-nutrients. Lentil is an important food legume in the semi-arid regions of the world where it can be grown successfully on limited soil moisture and in relatively poor soils. The inclusion of lentils in rotations also benefits succeeding crops as a result of biological nitrogen fixation. Chapter 3 reviews the global production of lentils, including production regions and their agro-ecologies, and shows how breeding methods and technology, and the use of new varieties with higher yield potential and improved disease resistance, have led to increased productivity in many countries. It discusses successful attempts to broaden the genetic base of lentil in South Asia and to cross domestic varieties with wild relatives to access new disease-resistance genes. Finally, it considers the scope for breeding new climate-smart varieties of lentil in response to emerging climate changes and variability.

Chapter 4 describes the climate, land and nutrient requirements for lentil cultivation, before going on to address agronomic practices used in lentil-producing countries, including methods of land preparation, sowing, harvesting, threshing and cleaning. Procedures used in developed countries where the crop is entirely mechanized are also included, as well as innovations in lentil cropping systems. The chapter suggests improvements to seed supply systems, seed varieties, planting methods, weed control and harvesting methods.

After discussing research on the soybean genome, Chapter 5 describes methods for developing and using DNA markers derived from genomic sequences for monogeneic, oligogeneic and polygeneic traits, together with examples of successful mapping, fine mapping and gene isolation. The chapter discusses identification of polymorphism, genetic and association map development, and marker-assisted selection (MAS) of the recurrent parent genome. It also looks at MAS in recurrent cross populations, and the scoring of phenotypes, before examining ways in which marker-assisted selection can be used to isolate and select desirable traits in soybeans.

Soybean production in sub-Saharan Africa (SSA) has increased significantly in response to demand arising from increasing populations and improved incomes, though many countries still reply on imports There is therefore an urgent need to further improve the production of this important legume. Chapter 6 discusses trends in soybean production and consumption across the region, and reviews best practices for soybean cultivation, together with evidence for their effectiveness in improving soybean yields. These best practices include use of improved varieties, inoculation, improved crop management, as well as nutrient, disease and pest management. The authors discuss the importance of supporting these practices with good input delivery and financing systems, agricultural advisory services and functioning output markets.

Groundnut is an important nutrient-dense crop grown in over 100 countries. Breeding for improved varieties is critical for increasing yields and enhancing quality. Chapter 7 describes the genetic resources of groundnut and their potential for mining desirable traits, potential breeding targets and ways to maximise groundnut oil quantity and quality. The chapter provides a detailed case study of groundnut production in Uganda, and outlines the potential benefits of improved groundnut varieties, including disease resistance, as well as suggesting future directions for groundnut research.

Groundnut is largely grown under rainfed conditions in Asia and Africa by resource-poor small-holder farmers, requiring low-cost technologies based on locally-available resources. The diverse growing conditions of the crop necessitate development of crop management techniques to meet specific requirements. Genetic and management techniques can realize optimal groundnut pod yield, meet the needs of processors and consumers, and ensure food safety standards. Chapter 8 discusses the limitations of current agronomic guidelines, as well as best practice in field preparation, soil resource management, seed preparation, planting, weed and water management, as well as plant protection. The chapter goes on to describe harvesting, drying, curing and storage processes, as well as trends in seed production.

Aflatoxin contamination of crops and food poses a substantial threat to humans and livestock worldwide. Preventing various *Aspergillus* species from becoming established and growing on peanuts (groundnut, *Arachis hypogaea* L.) can reduce aflatoxin contamination. Chapter 9 describes factors that affect the growth of *A. flavus* and *A. parasiticus* on groundnuts. The chapter also discusses the use of models to predict contamination, as well as cultural and biological control measures designed to minimize contamination. The chapter also features three case studies from current value chain projects in Ghana, Haiti, and Malawi. The chapter argues the need for a more focused and concerted effort to address the issue of aflatoxin contamination in groundnuts.

Part 2 Cultivation of cowpea, faba beans and pigeonpea

Cowpea is a legume crop of vital importance to the livelihoods of millions of people, providing a nutritious grain and an inexpensive source of protein for both rural poor and urban consumers. It is grown for both food and animal feed and is an integral component of various cropping systems in the semi-arid tropics and sub-tropics covering over 65 countries. Chapter 10 describes production constraints, existing cowpea breeding programs and past challenges, with a particular focus on cowpea breeding at the International Institute for Tropical Agriculture (IITA). The chapter gives an account of progress in breeding improved varieties made to date, including cowpea international trials, and suggests lines of research for the future.

Chapter 11 examines what constitutes an optimal cowpea plant population and explains how to integrate the crop in intercropping systems in West Africa. The chapter explores how planting dates can be manipulated to improve cowpea productivity, and how nutrient management can be used to increase cowpea yields. Finally, the chapter examines the application of Integrated Pest Management (IPM) in cowpea production and looks ahead to future trends in this area.

The faba bean is an important cool-season food legume crop grown under different cropping systems for food, animal feed and as a green manure. Chapter 12 discusses key advances in producing new varieties of faba bean that can achieve high nitrogen fixation, are tolerant of heat, drought and herbicides, as well as varieties resistant to broomrape, and disease. The chapter looks ahead to future research trends in this area.

Faba bean is mainly grown under rain-fed conditions, although irrigated production is important in Egypt, parts of China and Central Asia. The main focus of Chapter 13 is faba bean cultivation under rain-fed growing conditions, covering production in China, West Asia, North and East Africa. The chapter discusses the diseases, weeds and pests affecting this crop and ways they can be managed. It also reviews faba bean breeding, genetic resources and markers for breeding, water deficit management, tillage systems, biological nitrogen fixation (BNF) and mineral nutrient requirements.

Pigeonpea is a high protein pulse crop that grows well under biotic and abiotic stress situations. It has the potential to play a significant role in meeting the challenges of food security in the tropics and sub-tropics. Chapter 14 examines the role of pigeonpea in global nutritional security for humans and animals, and addresses the physical, environmental and genetic factors that may affect the sustainability of pigeonpea production. The chapter examines four ways of enhancing pigeonpea production: through crop modelling, an efficient seed system, plant breeding and hybridization. Finally, the chapter considers the latest trends in pigeonpea breeding and production.

Production of pigeonpea is constrained by poor agronomic practices such as improper methods of sowing, incorrect sowing time, inadequate seed rate, insufficient weeding, inappropriate fertilization and insufficient irrigation. Low plant densities, low soil fertility, insufficient weeding and insufficient/inappropriate use of fungicides and herbicides may also be constraints. Chapter 15 discusses seeds and sowing, and analyses integrated crop management techniques for pigeonpea with an emphasis on efficient fertilizer, nutrient management and water use to maximize sustainable yields. The chapter examines the role of weed management and the potential contributions of pigeonpea hybrid cultivars, early maturing pigeonpea varieties, as well as rabi and summer pigeonpea. It concludes by looking at harvesting, threshing and storage techniques, before looking ahead to future trends in this area.

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