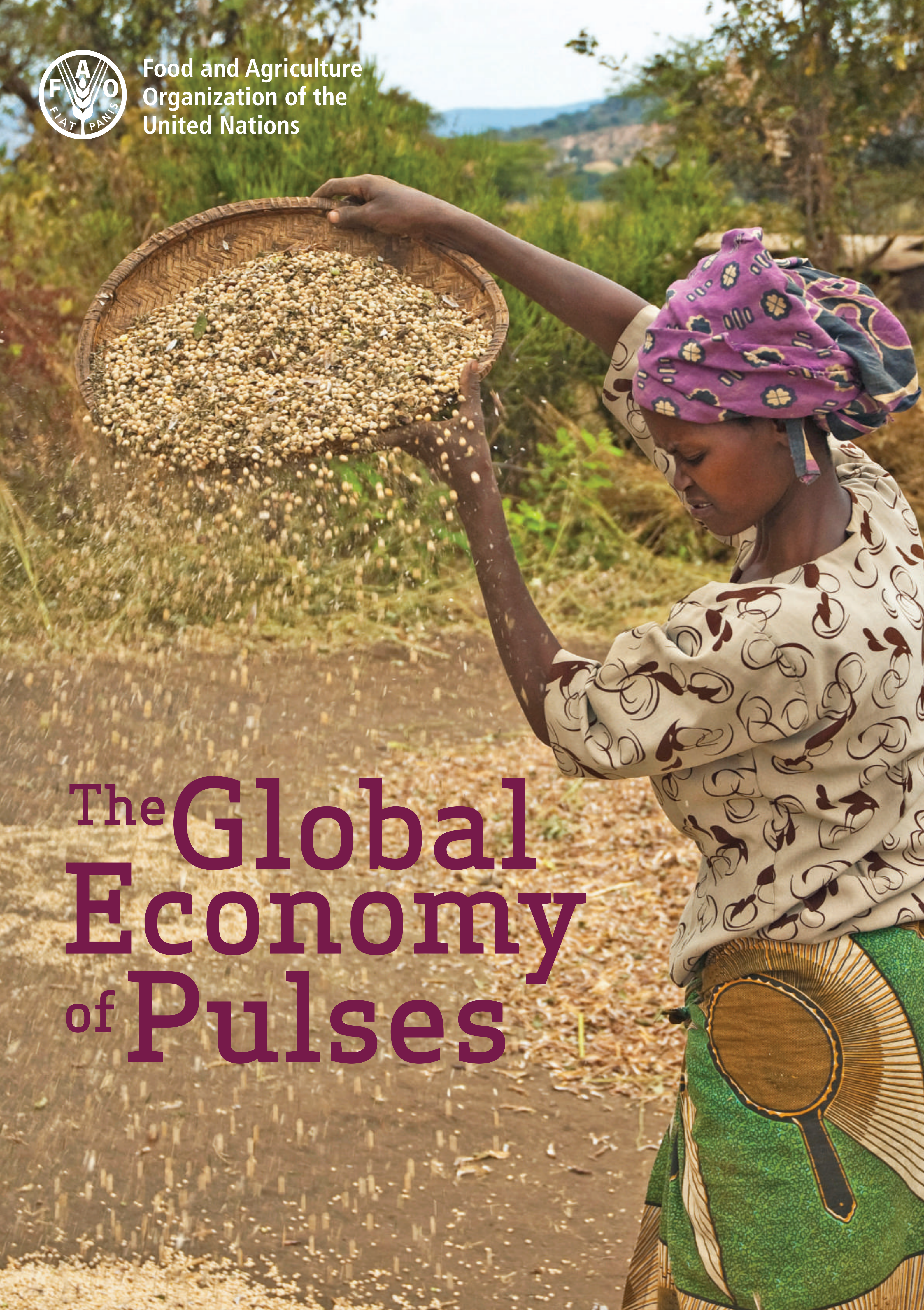

Food and Agriculture Organization of the United Nations

The Global Economy of Pulses

The Global Economy of Pulses

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NUTRITIOUS SEEDS FOR A SUSTAINABLE FUTURE

In 2013, the United Nations General Assembly declared 2016 as the International Year of Pulses (IYP), nominating FAO as the organization responsible for implementing the Year in collaboration with relevant stakeholders. The Trade and Markets Division is one of three FAO technical Divisions that have contributed actively to the implementation of the Year. The Division maintains a constant watch on the world market situation and outlook for all the main agricultural commodities, focusing on global issues that affect the production, trade, distribution and consumption of agricultural products, and prepares factual and interpretive surveys of the world commodity economy.

As a distinct contribution to the International Year of Pulses, FAO's Trade and Markets Division coordinated the preparation of this study on *The Global Economy of Pulses*. Having been endorsed by the IYP Steering Committee as a key activity of the Year, and having been sponsored in part by the Year's Multilateral Trust Fund, this study seeks to illustrate the world pulses situation and recent market trends, covering the themes of production, yields, utilization, consumption, international trade and prices, as well as providing a medium-term outlook for pulses.

Pulses have been an essential part of the human diet for centuries, yet their nutritional value is not generally recognized and the average level of consumption of pulses remains low. The International Year of Pulses 2016 went a long way to reverse these perceptions and bring to light the crucial roles that pulses play in healthy diets, sustainable food production and, above all, in food security. Pulses truly are nutritious seeds for a sustainable future, and can make an important contribution to the achievement of many of the Sustainable Development Goals of the 2030 Agenda for Sustainable Development.

To do so however, a number of conditions have to be met. Based on a comprehensive survey of relevant literature and a detailed analysis of quantitative data, *The Global Economy of Pulses* shows that there is a pressing need to close the large gap between potential and actual yields, particularly on smallholder farms, including by adopting improved varieties and modern agronomic practices throughout developing countries. This in turn requires a major thrust in agricultural research and extension, improving credit availability, and public investment.

The report presents latest data as they were available until 2016. On many aspects of the economy of pulses, more recent data have since become available. While the analysis presented in the report remains extremely valuable and relevant, the Trade and Markets Division of FAO is committed to bring out a supplementary volume shortly to present updated trends on different aspects of the economy of pulses.

Rome
1 September 2019

Boubaker Ben Belhassen
Director, Trade and Markets Division
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FAO commissioned two background papers for this report: one by Merritt Cluff titled 'The Medium-Term Market Prospects for the Global Market for Pulses', and the other by Serecon Inc. on 'Value Chains and Patterns of Global Trade in the Pulses Sector'. The SSER also commissioned two background papers for this report: 'Policy Support for Export-oriented Production of Pulses in Australia' by Smitha Francis and 'Futures Markets for Chickpea: A Case Study from India' by Mandira Sarma. We are thankful to all of them.

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INTRODUCTION

Boubaker Ben Belhassen, Vikas Rawal, Dorian Kalamvrezos Navarro

Pulses are edible dry seeds of plants belonging to the *Leguminosae* family. They are consumed in the form of whole seed, split grain, dehulled split grain and flour.[1] Many different types of pulses are grown the world over. Of these, the major ones, in terms of global production and consumption quantities, are the common bean, chickpea, dry pea, lentil, cowpea, mung bean, urd bean and pigeonpea. In addition, there are a large number of minor pulses that are grown and consumed in different parts of the world. While pulses are primarily grown for human consumption, there is, in addition, substantial demand for them as animal feed in some of the developed countries. Of the various pulses, dry pea, faba bean and lupins are widely used as animal feed.

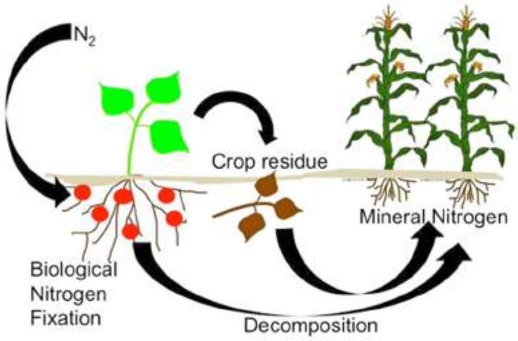
The pulse grain has a pair of cotyledons which make up its edible part. There are two aspects of pulses that distinguish them from most other food crops.

First, they are very nutritious and their consumption is associated with many health benefits (see Chapter 2). They are rich in proteins and minerals, have high fibre content and low fat content, and no cholesterol. The carbohydrates in pulses are absorbed and digested slowly, and thus help control diabetes and obesity.

Secondly, pulses, like other plants of the *Leguminosae* family, have root nodules which absorb inert nitrogen from soil air and convert it into biologically useful ammonia, a process referred to as biological nitrogen fixation. The root nodules are formed by soil-borne rhizobia bacteria that attach themselves to the roots of these plants. In the symbiotic relationship that forms between the plant and these bacteria, the plant provides nutrients and energy to

1 The pods and seeds of many leguminous plants, such as green bean or green pea, are also eaten as green vegetables. These are classified as legumes rather than as pulses. Similarly, leguminous crops used primarily for the extraction of edible oil – such as soybean and groundnut – are not classified as pulses and are instead treated as oilseeds.

Figure 1.1: Nitrogen fixation in pulse crops



Source: Nape Mothapo, North Carolina State University.

the bacteria, and the bacteria in turn produce nitrogen that helps growth of the plant. While most of the nitrogen is used for plant growth, a part of it is released into the soil when the bacteria die and some more when plant residue decomposes (Figure 1.1). Consequently, the pulse crops do not need any additional nitrogen as fertilizer and, because of the release of excess nitrogen in the soil, the requirement of fossil fuel-based chemical nitrogen fertilization in crops that follow in the cropping cycle is also reduced.

These properties of pulses make them an indispensable ally in the fight against malnutrition, in particular protein malnutrition, and in reducing the use of fossil fuels in agriculture. However, although pulses have an important role to play in raising the levels of human nutrition and in maintaining the environmental sustainability of agriculture, low yields and low returns are factors that have historically constrained their growth.

Global Trends in Production

In the triennium ending 2014, the annual global production of pulses was about 77 million tonnes (Table 1.1). Of this, the production of dry bean accounted for about 24 million tonnes, chickpea production for about 13 million tonnes, dry pea production for about 11 million tonnes and cowpea production for about 7 million tonnes. The annual production of lentil in the same triennium was estimated to be 5 million tonnes, while that of pigeonpea and faba bean was about 4 million tonnes each. The combined annual production of all other pulses – including bambara bean, lupins, vetches and pulses that are not separately classified – was about 7 million tonnes.[2]

The global production of pulses was about 3.5 percent of the global production of cereals in the early 1970s. Given the slow rate of growth over the last five decades, the global ratio of pulse production to cereal production declined further, to about 2.8 percent, by the triennium ending 2014. In the early 1970s, the average per hectare yield of pulses was about one-third of average per hectare cereal yield. With a higher growth rate in per hectare yield of cereal crops, the gap between the yields of cereal and pulse crops has widened over the decades. In the triennium ending 2014, the average yield of pulse crops was just about a quarter of the average yield of cereal crops.

Since the 1970s, there have been two phases of high growth in the production of pulses. The first phase, over the 1980s, saw the annual production of pulses increase from about 36 million tonnes at the start of the decade to about 48 million tonnes by the end of the decade. In this period, the growth of pulses production was led by dry pea production. Increased dry pea production over the 1980s was a result of a simultaneous increase in yields (at a rate of 5.3 percent per annum) and expansion of area (at a rate of 4.2 percent per annum). In the triennium ending 1991, at about 2 tonnes per hectare, the average global yield of dry pea was higher than the average yield of all other pulses.

The period of high growth of production in the 1980s was followed by a period of stagnation in the decade of the 1990s. The production of

2 The FAOSTAT category 'pulses nes' refers to pulses 'not elsewhere specified'. This category includes pulses that may be of minor importance in a country and are thus not classified separately in the national statistics. For example, in the Indian statistics, cowpea, common bean, moth bean and a host of pulses grown by indigenous communities are not separately classified, and are reported under minor pulses. The category 'pulses nes' also includes crops that may be classified separately in the national statistics of a few countries but are not separately classified in FAOSTAT. For example, *Lathyrus sativus* (grass pea) is a major pulse crop in Nepal and Bangladesh, but is not separately classified in FAOSTAT.

Table 1.1: Global production of pulses and cereals, trienniums ending 1971, 1981, 1991, 2001, 2011 and 2014 (million tonnes)

Year	Dry bean	Chickpea	Dry pea	Cowpea	Lentil	Pigeon pea	Faba bean	Other pulses	Total pulses	Cereals
1971	12	7	9	1	1	2	4	6	43	1221
1981	14	6	8	1	1	2	4	4	41	1573
1991	17	7	15	2	2	3	4	6	57	1905
2001	18	8	11	4	3	3	4	6	56	2085
2011	23	11	10	6	4	4	4	6	68	2518
2014	24	13	11	7	5	4	4	7	77	2712

Note: Other pulses include lupins, vetches, bambara bean and pulses not separately classified in FAOSTAT.
Source: FAOSTAT data, updated using national statistics.

Table 1.2: Global yields of pulses and cereals, trienniums ending 1971, 1981, 1991, 2001, 2011 and 2014 (kilograms per hectare)

Year	Dry bean	Chickpea	Dry pea	Cowpea	Faba bean	Lentil	Pigeonpea	All pulses	Cereals
1971	532	652	1164	237	966	605	694	670	1789
1981	555	624	1099	377	1177	611	676	669	2195
1991	628	706	1696	402	1508	752	722	819	2690
2001	750	766	1773	414	1501	827	722	848	3101
2011	784	901	1600	520	1755	1040	779	889	3597
2014	824	956	1616	614	1807	1152	718	929	3784

Source: FAOSTAT data, updated using national statistics.

dry pea fell sharply over the 1990s, and the slow growth of dry bean, chickpea and cowpea over the decade was barely enough to compensate for the decline in dry pea. After a decade-long stagnation, pulse production started looking up once again after 2001.

Between 2001 and 2014, the last year for which data on pulse production are available, the global production of pulses increased by over 20 million tonnes. This increase came about primarily on account of an increase in the production of common bean, chickpea, cowpea and lentil. Globally, between 2001 and 2014, the annual production of dry bean increased by about 7 million tonnes. In the same period, the annual production of chickpea went up by about 5 million tonnes, that of cowpea by about 3.8 million tonnes and that of lentil by about 1.6 million tonnes. While the largest increase in absolute levels of production was in the case of dry bean (Table 1.1), the most striking yield growth over this period was seen in the case of lentil, cowpea and chickpea (Table 1.2). In the triennium ending 2014, among the major pulses, average yields were highest for faba bean (1,807 kilograms per hectare), followed by dry pea (1,616 kilograms per hectare), lentil (1,152 kilograms per hectare) and chickpea (956 kilograms per hectare). Notwithstanding a spurt in growth in recent years, cowpea had a lower average yield (614 kilograms per hectare) than all other pulses (Table 1.2).

Table 1.3: Share of different regions of the world in production of major pulses, 2012–14 (percent)

Region	Dry bean	Chickpea	Dry pea	Cowpea	Lentil	Pigeonpea	Faba bean	All pulses
East Asia	6.1	0.1	13.4	0.2	3.0	0.0	37.3	6.4
Southeast Asia	17.9	3.8	0.6	1.8	0.0	12.8	0.0	7.7
South Asia	17.3	74.3	7.6	0.2	30.2	67.8	0.1	27
West Asia	0.9	4.8	0.1	0.0	10.5	0.0	1.5	2.1
Caucasus and Central Asia	0.5	0.1	0.8	0.0	0.1	0.0	0.3	0.4
Oceania	0.3	5.9	2.8	0.0	7.7	0.0	7.8	4.3
Europe	2.3	1.2	29.1	0.3	1.8	0.0	14.2	8.4
North Africa	0.4	0.8	0.5	0.9	0.8	0.0	13.1	1.4
Sub-Saharan Africa	24.0	4.7	5.5	95.5	3.1	16.7	21.1	22.8
North America	6.4	2.3	37.9	0.3	42.4	0.0	0.0	10.7
Latin America and the Caribbean	24.0	2.1	1.7	0.8	0.3	2.7	4.7	8.9
World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

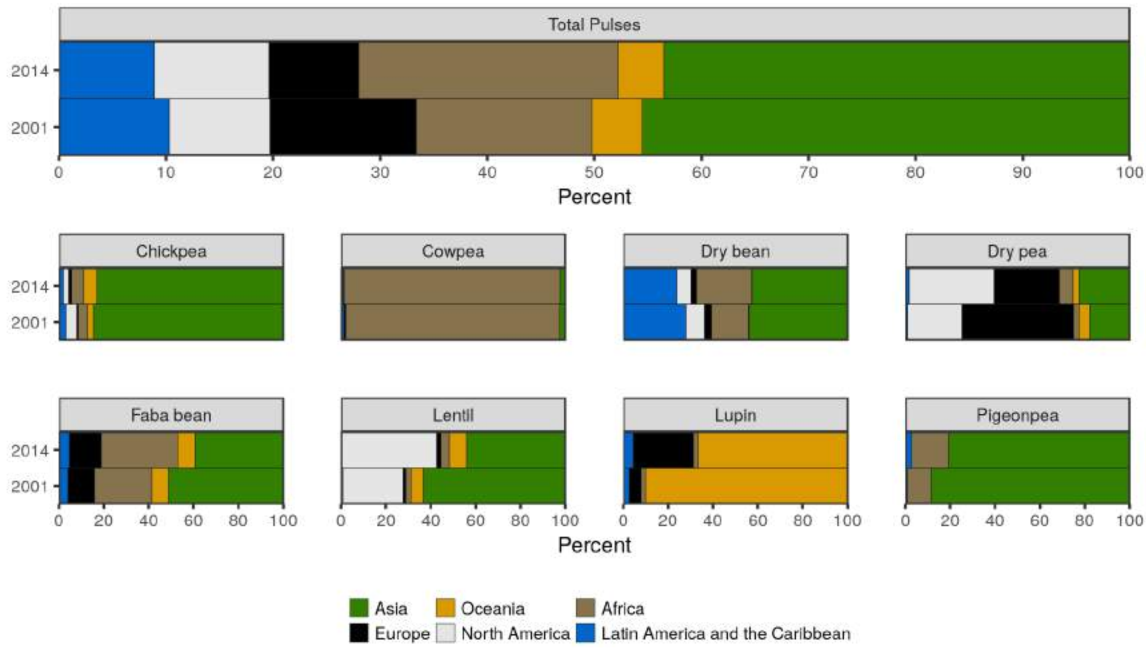
Note: The sum of rate of growth of area and yield measures the rate of growth of total production. In periods when either area or yield growth is negative, the net effect of growth of area and yield measures the rate of growth of total production.
Source: FAOSTAT data, updated using national statistics.

Regional Distribution of Production

Table 1.3 shows the regional distribution of production of different types of pulses in the triennium ending 2014. While pulses are produced in every region of the world, South Asia and sub-Saharan Africa together account for about half of global production. Cultivation of dry bean, a category comprising many different types of beans, is the most widespread across different regions of the world. In 2012–14, sub-Saharan Africa accounted for 24 percent of global production of dry bean, Latin America and the Caribbean for about 24 percent, Southeast Asia for about 18 percent, and South Asia for about 17 percent. In contrast, global chickpea cultivation was more concentrated, with about 74 percent of total production coming from South Asia alone. Pigeonpea production was also concentrated in South Asia (68 percent), although there has been an increase in the shares of sub-Saharan Africa (16.7 percent) and Southeast Asia (12.7 percent – mostly in Myanmar). Dry pea is produced primarily in North America (38 percent) and Europe (29 percent). Cowpea, a legume specific to arid regions, is primarily grown in sub-Saharan Africa, which accounted for about 96 percent of global production in 2012–14. North America is the largest (42 percent) producer of lentil, followed by South Asia (30 percent).

Figure 1.2 shows the changes in shares of different regions of the world in the production of pulses between 2001 and 2014. The figure shows that there was an increase in the shares of North America and Africa, and a decline in the share of Europe. Africa's share increased in the production of almost all pulses. North America increased its share primarily in the production of dry pea and lentil. Europe, once the largest producer of dry pea, saw a sharp decline in overall production of pulses. Although Asia remained a major producer of many pulses, its share in global production declined between 2001 and 2014.

Figure 1.2: Share of different regions of the world in production of pulses, by crop, trienniums ending 2001 and 2014 (percent)



Source: FAOSTAT data, updated using national statistics.

Exports and Imports of Pulses

Over the last four decades, there has been a steady increase in the quantity of pulses traded internationally (Figure 1.3). Between the trienniums ending 1971 and 2013, the quantity of pulses exported went up about seven times, from only about 1.9 million tonnes to over 13 million tonnes (Table 1.4). In the triennium ending 1971, only 4 percent of total pulse production was traded internationally; by the triennium ending 2013, this had increased to 18 percent. With an increase in trade liberalization across the world, the last two decades have seen a particularly large increase in international trade (Figure 1.3).

Figure 1.4 shows the shares of different regions of the world in exports and imports of pulses in 2011–13. The figure shows that North America is the largest exporter of pulses. In 2011–13, 44 percent of all pulses that were exported were from North America. It particularly dominated the world exports of lentil and dry pea, with 76 percent of lentil exports and 71 percent of dry pea exports originating in North America. Other than North America, Oceania is a net exporter of pulses with 10 percent of the exports of pulses originating there; it accounts for only 0.3 percent of world imports. Oceania specializes in the production of chickpea and faba bean: it accounted for 34 percent of world exports of chickpea and 42 percent of world exports of faba bean.

Asia, Africa, Europe, and Latin America and the Caribbean have a greater share in world imports than in world exports. Asia, with a large demand for pulses, accounts for 64 percent of global imports. Asia's share in imports is higher than its share in exports for all pulses other than dry bean. Figure 1.5 shows that there has been a sharp increase in Asia's dependence on imports of pulses since 2001. This is primarily on account of an increasing shortfall in the domestic supply of pulses in India, and China's transformation from being a net exporter of pulses to being a net importer (Heine, 2016). In contrast, imports by European countries, which surged in the 1980s, declined sharply after the mid-1990s. A substantial part of pulses in Europe is used for animal feed. Since the 1990s, Europe's dependence on pulses declined as it shifted to soybean as the primary source of plant protein in animal feed.

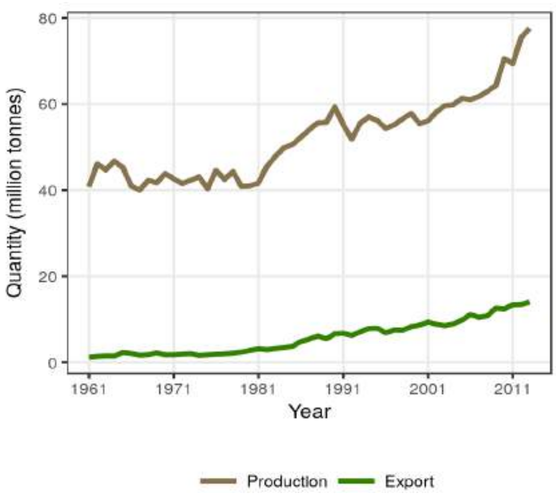
Table 1.4: Global exports of different pulses, trienniums ending 1971, 1981, 1991, 2001 and 2013 (thousand tonnes)

Crop	1971	1981	1991	2001	2013
Dry bean	636	1305	1820	2707	4235
Chickpea	122	205	475	769	1564
Dry pea	600	586	2557	3499	4516
Faba bean	158	189	508	512	780
Lentil	153	331	480	1060	2230
Other pulses	8	0	0	0	1
Total pulses	1918	2770	6280	8770	13624

Source: FAOSTAT data.

Value chains have become exceedingly important with the expansion of international trade. There are two specific reasons that make value chains in the pulses sector complex. First, pulses are highly susceptible to storage pests like bruchids. As a result, long-term storage requires controlled temperature and humidity. Considerable losses can occur in the absence of appropriate storage infrastructure. Secondly, a substantial proportion of pulses, particularly in Asia, are consumed after milling. Both these factors result in long value chains, high seasonal fluctuations in prices, and a considerable gap between the prices received by producers and the prices paid by final consumers.

Figure 1.3: Production and exports of pulses, 1961 to 2013 (million tonnes)



Source: FAOSTAT data, updated using national statistics.

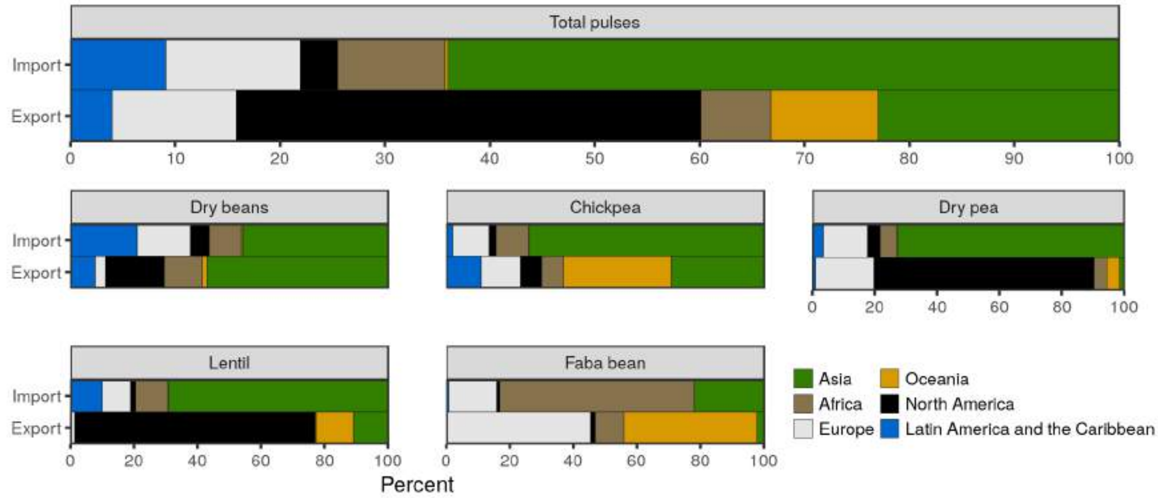
Scope and Plan

The global economy of pulses has seen substantial changes over the last fifteen years. The growth of pulse production accelerated after 2001, and, between 2001 and 2014, annual production of pulses increased from 56 million tonnes to 77 million tonnes. This report provides an overview of the global economy of pulses, and presents an analysis of the dynamics of growth of major pulses in different pulse-producing countries of the world.

Chapter 2 looks at trends and regional variations in the levels of consumption and sources of demand for pulses across the world. Although the average level of consumption of pulses has been stagnant globally, at about 21 grams per capita per day, over the last three decades, aggregate demand has grown in the Indian subcontinent and in sub-Saharan Africa.

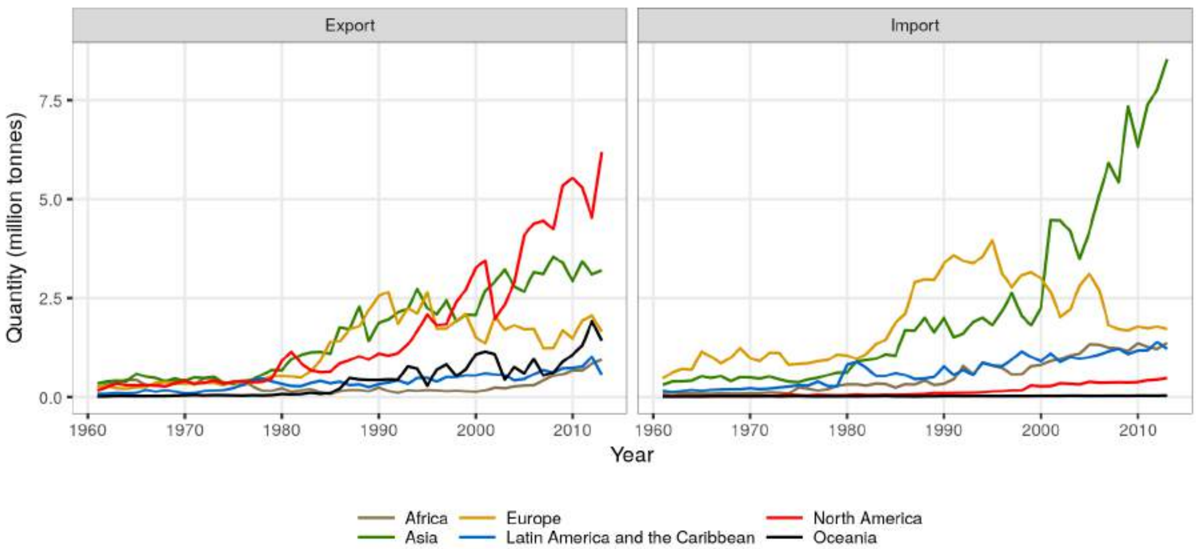
Pulses are cultivated under diverse conditions: on homestead gardens, smallholder farms, as well as large-scale, industrial farms; as sole crops, intercrops and boundary crops. The extent and levels of adoption of modern technology, yields and incomes vary across crops, countries and different production systems. Production conditions, and constraints and extent of growth also vary considerably across various pulse crops. In order to arrive at an understanding of the global pulses economy, the factors that constrain or facilitate growth in production need to be analysed separately for each crop and for the major pulse-producing

Figure 1.4: Share of different regions of the world in global exports and imports of pulses, 2011–13



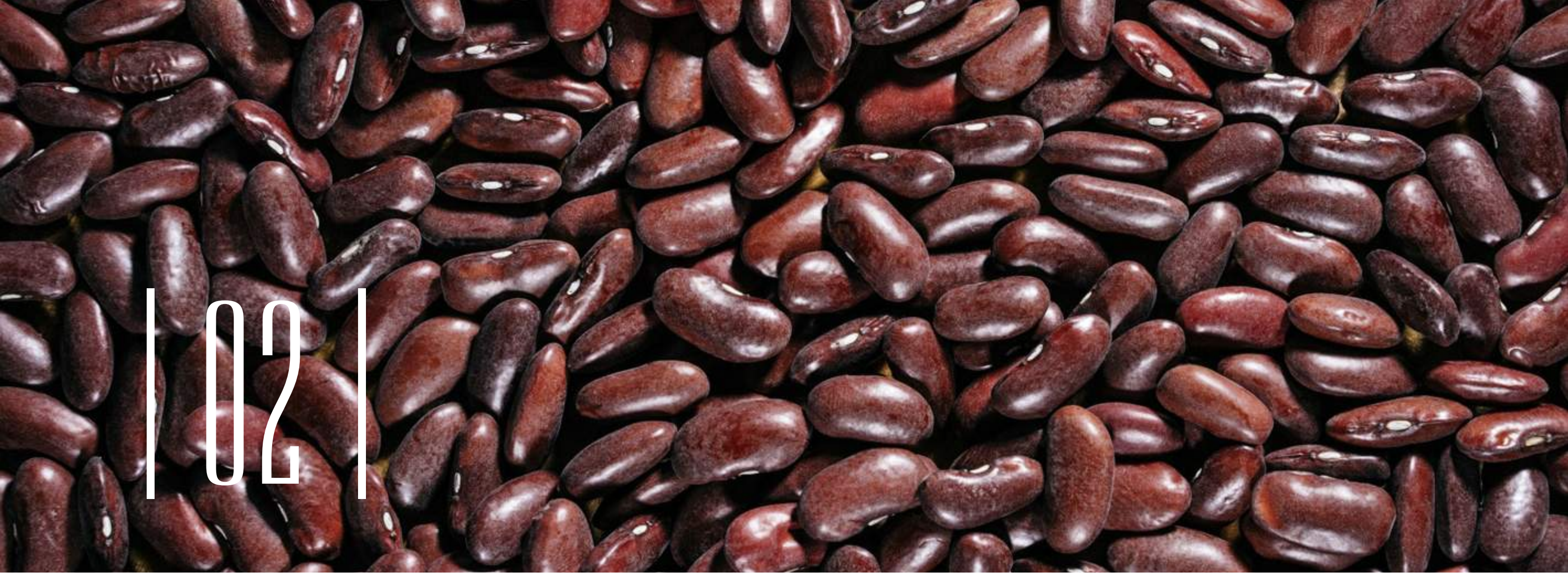
Source: FAOSTAT data.

Figure 1.5: Trends of exports and imports of pulses, different regions of world, 1960 to 2013



Source: FAOSTAT data.

countries. Hence, this report examines the trends and patterns of growth, and the factors that explain these, separately for chickpea (Chapter 3), pulses of *Phaseolus* and *Vigna* genera (Chapter 4), lentil (Chapter 5), pigeonpea (Chapter 6), dry pea (Chapter 7), and pulses of *Vicia* genus (Chapter 8). For each of these crops, the production conditions and dynamics of growth are discussed for the major producing countries. Chapter 9 discusses price formation, the functioning of markets and the value chains of pulses. Finally, the report discusses future prospects and policy imperatives for sustaining the growth of pulse production (Chapter 10).



PULSES: NUTRITIONAL BENEFITS AND CONSUMPTION PATTERNS

Vikas Rawal, Ruth Charrondiere, Maria Xipsiti, Fernanda Grande

The nutritional benefits of pulses make them a valuable component of healthy food systems. However, data on consumption of pulses show that their average per capita intake is much lower than the recommended levels and has remained stagnant globally, at about 21 grams per capita per day, since the last three decades. Increased levels of consumption of pulses require increased availability, improved economic access and higher awareness of their nutritional value.

The Nutritional Content of Pulses and Their Effect on Health

Pulses are extremely nutritious. They have higher levels of protein, dietary fibre and minerals than all the major cereals. Further, they have very low fat content (Table 2.1).

It is a well-established fact that adequate intake of protein is crucial for the growth of infants and children, and protein-energy malnutrition among children has been found to be associated with stunting, wasting and cognitive deficits (Ghosh, Suri and Uauy, 2012; Kar, Rao and Chandramouli, 2008; WHO/FAO/UNU, 2007). Among adults, substantial intake of protein is essential for the building of muscles, and to facilitate repair and replacement of cells. Pulses contain about double the amount of protein found in wheat and about three times the amount of protein in rice. Of the major pulses, lupin has the highest level of protein at 34 grams per 100 grams, and pigeonpea and bambara bean have the lowest level at about 18 grams per 100 grams. Every 100 grams of lentil and urd bean have about 24 grams of protein.

The protein content also varies considerably across different varieties of each pulse grain. Based on a review of a large number of accession evaluations of various legume crops, Burstin *et al.* (2011) reported that protein content varies from 20.9 to 29.2 percent in the common bean, 15.8 to 32.1 percent in pea, 22 to 36 percent in faba bean, 19 to 32 percent in lentil, 16 to 28 percent in chickpea, 16 to 31 percent in cowpea, 21 to 31 percent in mung bean and 16 to 24 percent

Table 2.1: Nutrient profile of common pulses, relative to cereals (per 100 g edible portion on fresh weight basis)

Name	Energy (kcal)	Protein (g)	Fat (g)	Dietary fibre (g)	Available carbohydrate (g)
Pulses (whole)					
Adzuki bean, raw	318	20.5	0.6	13.1	51.3
Bambara bean, raw	325	18.4	6.4	28.9	33.7
Black turtle bean, raw	306	22.2	1.8	21.1	39.7
Chickpea, raw	337	20.4	5.2	20.7	42.0
Chickpea, *desi*, raw	332	21.2	5.0	21.2	40.0
Chickpea, *kabuli*, raw	359	20.8	6.1	13.1	48.9
Cowpea, raw	324	22.5	1.9	14.6	46.9
Faba bean, raw	309	25.3	1.4	20.8	38.3
Hyacinth bean, raw	316	23.2	1.5	16.2	44.2
Kidney bean, red, raw	307	22.8	1.6	21.7	39.4
Lentil, raw	324	24.4	1.5	17.0	44.8
Lupin, raw (*Lupinus spp.*)	309	34.1	6.5	35.3	10.8
Moth bean, raw	326	23.9	1.9	14.9	45.9
Mung bean, raw	325	20.9	1.3	15.4	49.6
Navy bean, raw	311	21.8	1.8	18.6	42.6
Pea, raw	310	23.4	2.1	22.2	38.4
Pigeonpea, raw	306	20.6	1.8	21.4	41.0
Pinto bean, raw	301	19.6	1.3	18.0	43.8
Rice bean, raw	312	18.8	0.5	15.2	50.3
Urd bean, raw	316	23.9	1.4	19.5	42.2
Cereals					
White maize flour, refined	354	7.6	2.9	5.5	72.0
White rice, polished, raw	353	6.1	0.5	1.1	81.0
Wheat flour, white	351	10.1	1.5	3.2	73.0

Source: FAO (2012), FAO (2016) and FAO/INFOODS Global Food Composition Database for Pulses (uPulses 1.0) Version 1.0.

in pigeonpea. The protein content of pulses is affected by both genetic and environmental factors. In general, a negative relationship is observed between protein content on the one hand, and starch and oil content on the other. Pulse varieties with high protein content generally tend to have low yields and small seed sizes. However, over the years, breeders have had some success in developing varieties with high yields without sacrificing protein content (ibid.).

Pulses are a particularly useful source of protein because the amino acids found in them complement the amino acids found in cereals. For instance, most cereals have low levels of lycine, whereas pulses are rich in lycine but have low levels of other amino acids like methionine.

Thus, if adequate quantities of both pulses and cereals are included in the diet, the requirement of the majority of amino acids essential for the human body can be met.

While pulses are an important source of protein, it must be noted that plant-based amino acids, including protein in pulses, have a lower bio-availability to humans than animal-based protein. Table 2.2 presents protein digestibility-corrected scores, which are a measure of the protein content after adjusting for digestibility of protein, for selected plant- and animal-origin foods. The table shows that pulses rank below foods of animal origin but well above all other plant-based foods in terms of protein digestibility-corrected scores.[1] The digestibility of protein can be improved through breeding (to reduce the content of anti-nutritional compounds like tannins), processing (like dehulling and splitting) and cooking. Soaking, germination and cooking (including pressure-cooking) are some of the effective, household-level methods that may be used to reduce the levels of phytates, polyphenols and tannins in pulse-based foods, and enhance the bio-availability of pulse proteins (Khandelwal, Udipi and Ghugre, 2010; Vidal-Valverde *et al.*, 1994).

Besides having higher protein content than other plant-based foods, pulses have other nutritional benefits as well. The dietary fibre content of raw pulses varies between 13–35 grams per 100 grams of edible portion. In contrast, white rice has just about 1 gram of fibre per 100 grams (Table 2.1). Pulses have both soluble and insoluble fibre. Soluble fibre slows down the absorption of lipids, fat and cholesterol in the human body, and thus helps to improve cardiovascular health (Halton *et al.*, 2006; Riccioni *et al.*, 2012). Insoluble fibre helps prevent gastrointestinal problems (Dahl, Foster and Tyler, 2012b). According to the US dietary guidelines (HHS and USDA, 2015), which recommend daily intake of dietary fibre for men and women of different ages in the US, men in the age-group 19–30 years should have a daily fibre intake of 33.6 grams and women in the same age-group should have a dietary fibre intake of 28 grams. The food-based dietary guidelines of many other countries provide similar information and recommendations.[2] It is

Table 2.2: Protein Digestibility-Corrected Amino Acid Scores (PDCAAS) for selected food items

Product	PDCAAS
Casein	1.00
Egg white	1.00
Beef	0.92
Pea flour	0.69
Pinto bean	0.57[c]/0.63[c]/0.62[a]
Kidney bean	0.68[c]
Navy bean	0.70[a]
Black bean	0.53[a]
Faba bean	0.47[a]
Lentil	0.52[c]/0.5[a]
Chickpea	0.71[c]/0.66[c]
Pea	0.68[a]/0.61[a]
Soybean protein	0.99[b]/0.92[d]
Soy assay protein	0.92
Pea protein	0.73[b]
Rapeseed protein	0.93[b]/0.83[d]
Sunflower protein	0.37[d]
Wheat gluten	0.25
Peanut meal	0.52
Whole wheat	0.40
Rolled oats	0.57
Rice-wheat-gluten	0.26

Notes: [a] autoclaved; [b] concentrate; [c] canned; [d] isolate
Source: Compiled by FAO (1989), Table 11 from different studies. Different values of PDCAAS for canned pinto bean and chickpea were reported in Eggum *et al.* (1989) and Sarwar *et al.* (1989).

1 A more recent Expert Consultation (FAO, 2011) recommends using the Digestible Indispensable Amino Acid Score (DIAAS) for evaluating the quality of proteins in food items and diets. Pulses are ranked between cereals and foods of animal origin by both PDCAAS and DIAAS.

2 Available at http://www.fao.org/nutrition/education/food-dietary-guidelines/home/en/

clear that a substantial part of such requirements of fibre intake can be met by consuming one cup of pulses every day.

The carbohydrates found in pulses are slowly digestible carbohydrates, like oligosaccharides and resistant starch. Since these are not absorbed quickly by the body, they help contain blood sugar levels. As shown in Table 2.3, pulses have a low Glycemic Index, which is a measure of how quickly an item of food can increase blood sugar

Table 2.3: Average Glycemic Index of some common foods, derived from multiple studies by different laboratories

Dairy products and alternatives		Legumes		Snack products		Sugars	
Milk, full fat	39±3	Chickpea	28±9	Chocolate	40±3	Fructose	15±4
Milk, skimmed	37±4	Kidney bean	24±4	Popcorn	65±5	Sucrose	65±4
Ice cream	51±3	Lentil	32±5	Potato crisps	56±3	Glucose	103±3
Yoghurt, fruit	41±2	Soybean	16±1	Soft drink/ soda	59±3	Honey	61±3
Soy milk	34±4			Rice crackers/ crisps	87±2		
High carbohydrate foods		**Breakfast cereals**		**Fruit and fruit products**		**Vegetables**	
White wheat bread	75±2	Cornflakes	81±6	Apple, raw	36±2	Potato, boiled	78±4
Whole wheat/ wholemeal bread	74±2	Wheatflake biscuits	69±2	Orange, raw	43±3	Potato, instant mash	87±3
Specialty grain bread	53±2	Porridge, rolled oats	55±2	Banana, raw	51±3	Potato, french fries	63±5
Chapati	52±4	Instant oat porridge	79±3	Pineapple, raw	59±8	Carrots, boiled	39±4
Corn tortilla	46±4	Rice porridge/ congee	78±9	Mango, raw	51±5	Sweet potato, boiled	63±6
White rice, boiled	73±4	Millet porridge	67±5	Watermelon, raw	76±4	Pumpkin, boiled	64±7
Sweet corn	52±5	Muesli	57±2	Dates, raw	42±4	Plantain/ green banana	55±6
Spaghetti, white	49±2			Peaches, canned	43±5	Taro, boiled	53±2
Spaghetti, wholemeal	48±5			Strawberry jam/jelly	49±3	Vegetable soup	48±5
Rice noodles	53±7			Apple juice	41±2		
Couscous	65±4			Orange juice	50±2		

Source: Atkinson, Foster-Powell and Brand-Miller (2008).

levels (Dahl, Foster and Tyler, 2012b). Clinical trials have shown that the intake of pulses helps to stabilize blood sugar by reducing spikes after eating and improves insulin resistance (Lunde *et al.*, 2011; Marinangeli and Jones, 2012; Rizkalla, Bellisle and Slama, 2002; Seewi *et al.*, 1999).

Pulses are also a rich source of several micronutrients (Table 2.4). They are rich in B-vitamins like folate, and have high iron and zinc content. Iron helps prevent anaemia and iron

Table 2.4: Micronutrient profile of common pulses, relative to cereals (per 100 g edible portion on fresh weight basis)

Name	Iron (mg)	Magnesium (mg)	Phosphorus (mg)	Potassium (mg)	Zinc (mg)	Copper (mg)	Folate (µg/100gm)
Pulses (whole)							
Adzuki bean, raw	4.6	129	381	1240	5.02	1.09	640
Bambara groundnuts, raw	2.7	172	224	1330	1.94	0.69	-
Black turtle bean, raw	6.6	180	471	1830	2.82	1.00	440
Chickpea, raw	6.6	132	264	819	3.12	0.44	400
Chickpea, *desi*, raw	8.1	164	302	1080	3.26	0.57	390
Chickpea, *kabuli*, raw	5.9	114	254	767	3.11	0.37	400
Cowpea, raw	5.6	162	334	1280	2.91	0.74	640
Faba bean, raw	5.2	135	431	1190	3.55	0.82	250
Hyacinth bean, raw	5.9	417	357	1700	5.6	1.37	23
Kidney bean, red, raw	8.8	149	395	1300	3.23	0.76	310
Lentil, raw	7.1	66	291	752	3.55	0.41	150
Lupin, raw (*Lupinus spp.*)	6.0	213	502	1030	5.22	0.67	360
Moth bean, raw	7.2	190	204	1710	3.96	0.85	650
Mung bean, raw	4.4	139	350	1180	1.62	1.16	620
Navy bean, raw	8.0	166	404	1340	2.91	1.03	400
Pea, raw	4.5	112	309	944	3.32	0.24	170
Pigeonpea, raw	5.1	118	242	1530	5.32	1.33	340
Pinto bean, raw	6.5	198	438	1940	2.61	0.87	520
Rice bean, raw	6.0	201	303	1390	2.84	1.21	120
Urd bean, raw	7.4	202	351	1160	3.04	0.92	180
Cereals							
White maize flour, refined	1.2	-	-	-	1.53	-	29
White rice, polished, raw	0.7	-	-	-	1.10	-	20
Wheat flour, white	2.0	-	-	-	1.80	-	24

Source: FAO (2012), FAO (2016) and FAO/INFOODS Global Food Composition Database for Pulses (uPulses1.0) Version 1.0.

deficiency, and, in recent years, biofortification has been used to enhance the iron content of beans and lentil (Della Valle *et al.*, 2013; ICARDA, 2015; Kumar *et al.*, 2016b; Petry *et al.*, 2015).[3] Zinc is needed for the immune system of the human body. Important mineral micronutrients found in pulses include magnesium, phosphorus, potassium and copper: magnesium is crucial for nerve and muscle functions, the immune system, and for bones; phosphorus is needed for the bones; potassium is needed for the bones, muscle function and for the heart; and the body needs copper for the nervous system, immune system and for generating red blood cells. Regular consumption of pulses can help prevent illnesses due to deficiency of these micronutrients.

Sprouting pulses before consumption is popular in many countries. Sprouting is a simple and inexpensive method by which the nutritive value of pulses can be improved. Studies on the germination and sprouting of pulses have shown that sprouting significantly increases the phytochemical content, vitamin C content, protein digestibility and anti-oxidant activity (Guo *et al.*, 2012; Khattak *et al.*, 2007; Obizoba, 1991; Shah *et al.*, 2011).

There is evidence that links the consumption of pulses to lower risk of cardio-vascular diseases and diabetes (Ha *et al.*, 2014; Halton *et al.*, 2006). Consumption of pulses is associated with satiety and therefore also helps in weight management (Jenkins and Jenkins, 1995; Lunde *et al.*, 2011; Marinangeli and Jones, 2012; McCrory *et al.*, 2010; Rizkalla, Bellisle and Slama, 2002; Thorne, Thompson and Jenkins, 1983). Some of the 'anti-nutrients' found in pulses – for example, phytates and lectin – although known to inhibit the absorption of desirable micronutrients like iron and zinc, are now increasingly recognized for their anti-inflammatory characteristics and potential benefits against cancer (Dahl, Foster and Tyler, 2012b; Kalogeropoulos *et al.*, 2010; McIntosh and Topping, 2000; Messina, 2014; Roy, Boye and Simpson, 2010).

Trends and Patterns of Consumption

Globally, the average level of consumption of pulses is about 21 grams per capita per day, and it has been stagnant at that level for the last three decades.[4] There are considerable variations in consumption levels across regions and countries, and, within countries, across socio-economic classes (Figure 2.1). Of the different regions of the world, Latin America and the Caribbean, sub-Saharan Africa and South Asia have the highest levels of average per capita consumption of pulses. In the triennium ending 2013, the average level of consumption of pulses was 34 grams per capita per day in Latin America and the Caribbean, and 33 grams per capita per day in sub-Saharan Africa and South Asia (Table 2.5).

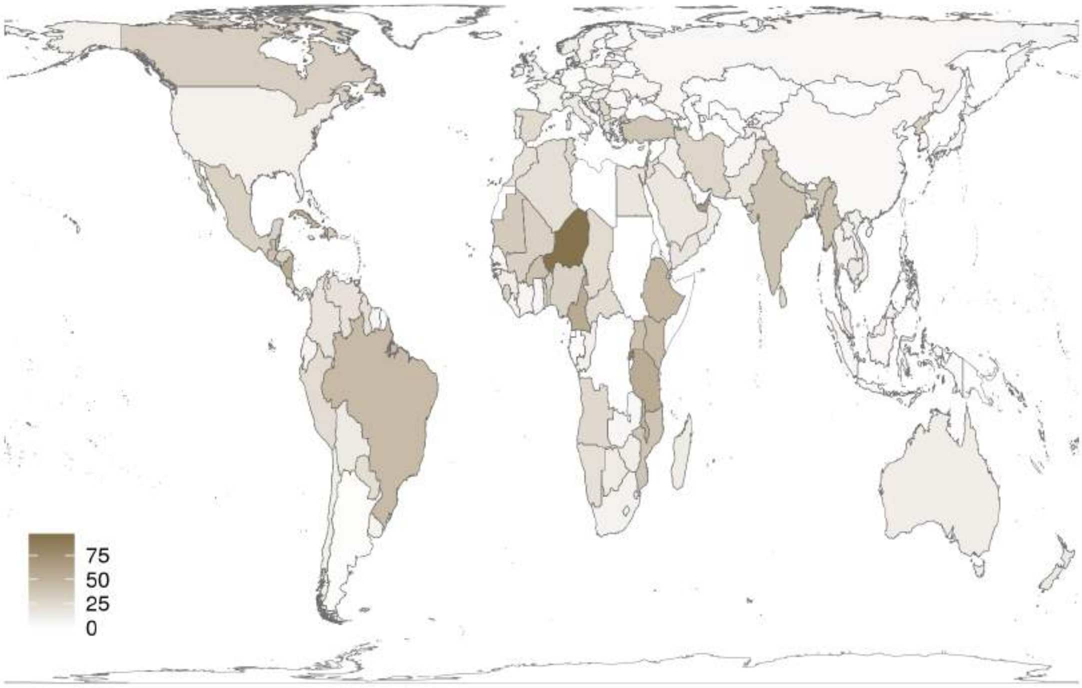
Although pulses are extremely nutritious, their per capita consumption levels have stagnated in most regions of the world over the last three decades, as mentioned above (Figure 2.2). Sub-Saharan Africa was the only region that saw a significant and steady rise in the consumption of pulses, from about 21 grams per capita per day in 1985 to about 32 grams per capita per day in 2010. In South Asia, and Latin America and the Caribbean, per capita consumption fluctuated around 30 grams per capita per day between the mid-1980s and 2010. In the rest of Asia and Oceania, per capita consumption declined from about 10 grams per capita per day in 1985 to only about 6 grams per capita per day in 2010. Per capita daily consumption has remained stagnant at about 20 grams in North Africa, about 7.5 grams per capita per day in Europe and about 12 grams per day in North America.

The consumption patterns of pulses are affected by several economic, historical and socio-cultural factors. Among the economic

3 Plant-based iron is less readily absorbed by the human body than iron found in foods of animal origin. But absorption of iron from pulses can be substantially increased if pulses are consumed with meat. Intake of vitamin C also improves iron absorption from pulses and other plant-based foods.

4 This section uses data from FAOSTAT on per capita supply of pulses for food consumption as a measure of average consumption of pulses. This variable in FAOSTAT is based on a supply-side measurement of availability of pulses for use as food.

Figure 2.1: Average daily consumption of pulses by country, 2011–13 (grams per capita per day)



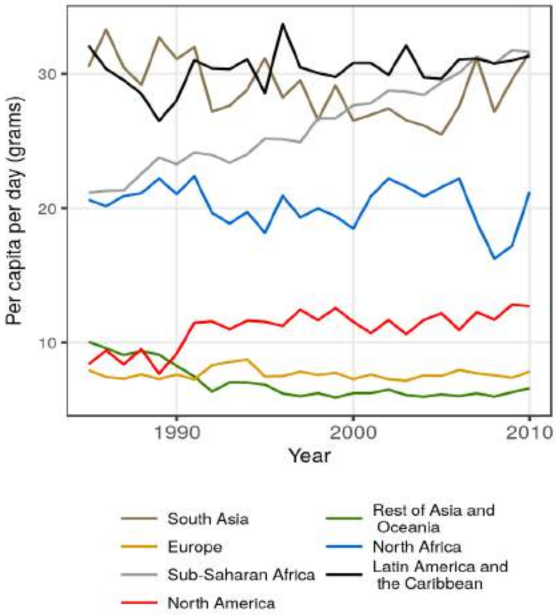
Source: FAOSTAT data.

Table 2.5: Average per capita per day consumption of pulses, and its contribution to protein and calorie intake, by region, 2011–13

Region	Average consumption (grams)	Share in total protein intake (percent)	Share in total dietary energy (percent)
Oceania	12	2	1
East Asia	4	1	0
Southeast Asia	9	3	1
South Asia	33	11	5
West Asia	19	6	3
Caucasus and Central Asia	1	0	0
Europe	7	2	1
North Africa	19	5	2
Sub-Saharan Africa	33	12	5
Latin America and the Caribbean	34	9	4
North America	11	2	1
World	21	6	3

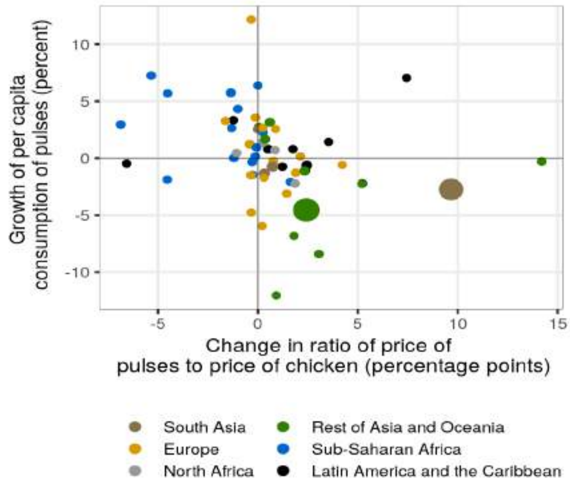
Source: FAOSTAT data.

Figure 2.2: Trends in consumption of pulses across different regions, 1985 to 2010



Source: FAOSTAT data.

Figure 2.3: Relationship between growth in consumption of pulses, and change in ratio of prices of pulses to prices of chicken, by country, 1985 to 2010



Notes: In the scatter plot, the size of each point is proportionate to the population of the country in 2010.
Consumer prices of one commonly consumed pulse were used for each region: prices of mung bean for South Asia, Southeast Asia and East Asia; prices of chickpea for West Asia, Central Asia and Oceania; and prices of bean for Latin America, sub-Saharan Africa and Europe.
Data on consumer prices from LABORSTA are not available for all the years for each country. Because of this, estimates for each country refer to the years for which data for that country were available in LABORSTA.
Source: For consumption data, FAOSTAT; for consumer prices, ILO's LABORSTA database.

factors, income levels as well as consumer prices influence the trends in consumption of food-commodities. Pulses are primarily included in the human diet as a source of protein. A decline in the consumption of pulses is associated with an increasing reliance on foods of animal-origin protein. With the growth of large-scale poultry, livestock and aquaculture industries, the ratio of prices of pulses to prices of foods of animal origin has increased in most regions of the world except for sub-Saharan Africa. This increase in the relative prices of pulses has led to an increasing reliance on foods of animal origin for meeting protein requirements.

Figure 2.3 shows the relationship between growth in the consumption of pulses, and average change in the ratio of prices of pulses to prices of chicken. The scatter plot of countries clearly shows a negative relationship between change in the ratio of prices and growth of consumption. In countries where the ratio of prices of pulses to chicken increased, which included most Asian and European countries, the consumption of pulses declined. On the other hand, in countries where the ratio of prices of pulses to chicken declined, which included the sub-Saharan Africa countries, the per capita consumption of pulses tended to increase.

Needless to say, relative prices are not the only economic factor that determines changes in the level of consumption of pulses. With an increase in incomes, the absolute levels of per capita consumption can rise despite a rise in relative prices. Similarly, with income contraction, absolute levels of consumption can fall despite an improvement in the relative prices.

In many parts of the world, pulses are considered a poor person's food, and people shift to other sources of protein in their diet as incomes increase. In the United States, for example, low-income households have been found to have higher consumption levels of beans than households with higher incomes (Lucier *et al.*, 2000). Leterme and Muñoz (2002) estimated that in the South American countries, low-income households consume 20 percent more beans than households in the highest income group.

The inverse relationship between income and level of pulse consumption, however, does not hold universally. In India, a major pulse-consuming country, large-scale surveys of consumption have consistently found a positive relationship between the levels of pulse consumption and incomes (Akibode and Maredia, 2012; Gupta and Mishra, 2014; Roy, 2011). Mfikwa (2015), a study based on large-scale national data on consumption in Tanzania, found that middle-income households consumed larger quantities of pulses than poor households. Low-income peasant households sold their produce after the harvest, and therefore did not have enough purchasing power to buy beans after their food reserves were exhausted.

Besides economic factors, historically and culturally determined dietary preferences, changes in tastes and eating habits, and levels of awareness – all affect trends in consumption. Cultural traditions have a strong influence on the type of pulses consumed in different regions and countries. In the United States, the consumption of bean is particularly concentrated among persons of Hispanic origin (Leterme and Muñoz, 2002; Lucier *et al.*, 2000; Mitchell *et al.*, 2009). In Myanmar, pulses are mainly consumed by people of Indian origin. In Brazil and Guatemala, black beans are largely consumed; in Nicaragua, the commonly consumed bean is small-sized and red in colour; in Colombia and Mexico, large, red-coloured beans are consumed; and in Peru, the demand is for white-coloured beans. In Indian and Pakistani Punjab, urd bean, mung bean and chickpea are widely consumed. In eastern India, Bangladesh and Nepal, lentil is the preferred pulse. In southern India, on the other hand, pigeonpea is the most widely consumed pulse. In China and many other East Asian countries, mung bean and adzuki bean are widely consumed.

The cooking of pulses, particularly when they are cooked as whole seeds, can be a time-consuming task. This has been a significant deterrent to the inclusion of pulses in the diet, especially in high-income countries. Some pulses contain a large quantity of slowly digesting carbohydrates like oligosaccharides that can cause flatulence, which also deters people from including these in their diet. In high-income countries, pulses are mainly sold as pre-cooked and canned products, while in developing countries they are primarily sold as dry grains. The availability of pulses in ready-to-consume form has been important as a contributory factor for sustaining consumption levels in high-income countries (Schneider, 2002). In South Asian countries pulses are mostly consumed as split grains, which take considerably less time to cook. The use of pressure cookers – which are energy-efficient and reduce the time taken to cook pulses – is also widespread in South Asia.

Pulses in Food-based Dietary Guidelines

Food-based dietary guidelines are national guidelines that translate recommended levels of nutrients in terms of food items, keeping in mind the specific nutritional and health requirements of the national population, the availability of different food items, and historical and cultural dietary traditions. Food-based dietary guidelines are an important informational tool for nutrition education.

With the FAO's assistance, about 100 countries have developed food-based dietary guidelines. An evaluation of these guidelines shows that about 87 percent of them recommend regular inclusion of pulses in the diet. However, the guidelines for most countries recommend the consumption of pulses in general terms without specifically pointing out their nutritional value or health benefits. The guidelines of about 27 percent of the world's countries mention that pulses are high-protein foods. Some of these guidelines club pulses with foods of animal origin as important sources of protein, while a few talk about the health benefits of reducing the consumption of meats and substituting it with pulses. Only 15 percent of national dietary guidelines refer to the high iron content of pulses; and 20 percent point to the fact that they contain high dietary fibre. In

Table 2.6: Level of daily intake of pulses recommended in the dietary guidelines for India (grams/day)

	Vegetarian diet with dairy products	Diet that includes a portion of egg/meat/fish
Infants (6–12 months)	7.5	–
1–3 years	30	15
4–6 years	30	15
7–9 years	60	30
10–12 years	60	30
13–15 years	60 (75)	30 (37)
16–18 years	75 (90)	37 (45)
Adults (of sedentary physical activity level)	60 (75)	30 (37)
Adults (of moderate physical activity level)	75 (90)	37 (45)
Adults (of heavy physical activity level)	90 (120)	45 (60)

Note: Figures in parentheses give the recommended level of intake for men for ages where a different level of intake is recommended for men and women. The introduction of egg, meat or fish among children is recommended at the age of 9 months.
Source: National Institute of Nutrition (2011).

just 8 percent of the guidelines, health benefits like management of obesity and diabetes are discussed.[5]

Even in countries where the national guidelines include specific recommendations and messages related to pulses, the extent of detail provided varies considerably. In some countries, as for example the United States and Malaysia, the guidelines provide specific details on nutrients. Only in a few cases are there specific recommendations regarding the quantity of pulses to be consumed. The guidelines for India, a country where pulse consumption is widely prevalent, provide very detailed information on the recommended levels of intake for adults and children, for men and women, for persons with different levels of physical activity, and separately for persons who consume meats and those who do not. For Indian adults, the guidelines recommend an intake of 60–120 grams of pulses per day if the diet includes plant-based food and dairy products, and 30–60 grams per day if the diet includes a portion of egg, meat or fish (Table 2.6). The dietary guidelines for the United States recommend one-and-a-half cups per week of legumes in a Mediterranean-style healthy diet, and three cups per week of legumes in a diet including eggs and dairy products but no meat (HHS and USDA, 2015). The dietary guidelines for Turkey recommend two servings per day from the group of meat, eggs and leguminous seeds, with 90 grams of pulses constituting a single serving.

It would be useful if the dietary guidelines for all countries imparted stronger messages on the nutritional and health benefits of pulses. These could then become the basis of further promotional activities that particularly target undernourished populations.

Conclusions

To sum up, pulses are extremely nutritious grains that are rich in protein, minerals and many other micronutrients. The amino acid profile of pulses complements the amino acid profile of cereals, because of which a combination of cereals and pulses in the diet can contribute to balanced protein intake. Unlike foods of animal origin,

5 This evaluation is based on the repository of national guidelines in FAO's Food-based Dietary Guidelines Database, available at http://www.fao.org/nutrition/nutrition-education/food-dietary-guidelines/en/

which are an alternative source of protein in the diet, pulses contain low levels of fat and little or no cholesterol. Pulses contain slowly digesting carbohydrates that help in the management of obesity, diabetes and cardiovascular ailments.

Given these nutritional and health benefits, it may be argued that increasing the consumption of pulses can be key to achieving better nutritional and health outcomes. It is, however, noteworthy that despite these nutritional and health benefits, the consumption of pulses in most parts of the world has been stagnating at low levels. Globally, the per capita intake of pulses is only about 21 grams per day. The reasons for this stagnation in the consumption levels of pulses are a combination of economic and non-economic factors.

Cross-country data on consumer prices show that the prices of pulses relative to that of alternative sources of protein have risen in most regions of the world other than sub-Saharan Africa. With the rise in large-scale poultry, livestock and aquaculture production, there has been a relative decline in the prices of foods of animal origin. This is consistent with the decline in consumption of pulses and rise in share of foods of animal origin in the diets of most regions of the world.

Consumption of pulses is also constrained by historical and cultural factors. While pulses are consumed in all parts of the world, different countries and communities consume different types of pulses, depending on their historical traditions. There are considerable variations in the levels and forms in which pulses are consumed across regions, ethnic groups and economic classes.

Long cooking time has been noted to be a factor that constrains the consumption of pulses. This has been effectively countered by soaking, pressure-cooking, and making available pre-cooked, ready-to-eat, canned pulses. Greater emphasis on the nutritional and health benefits of pulses in dietary guidelines, and on nutritional education and awareness programmes, is likely to help considerably in promoting the inclusion of pulses in human diets.

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CHICKPEA: TRANSFORMATION IN PRODUCTION CONDITIONS

Vikas Rawal and Prachi Bansal, with contributions from Kanika Tyagi

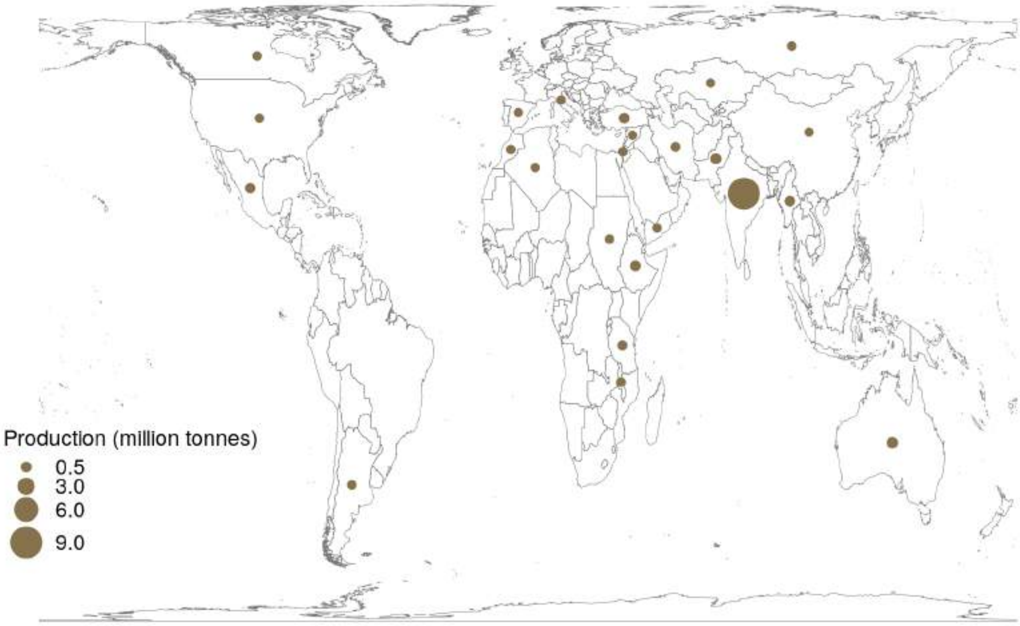
Introduction

Chickpea (*Cicer arietinum*) is one of the most important leguminous crops grown for human consumption. It is produced and consumed widely across different parts of the world (Figure 3.1). In the triennium ending 2014, the share of chickpea in global pulse production was about 17 percent, and it occupied about 17 percent of the total area under pulse cultivation worldwide. Chickpea is a self-pollinating legume that requires a cool climate during its initial growth period- with optimum temperatures ranging between 15°C and 25°C, and a warmer climate as it matures (Singh and Ali, 2003). It is a very rich source of easily digested protein, and is also rich in minerals such as magnesium, zinc, calcium, phosphorus and iron.

After a period of stagnation of about three decades, the last two decades have witnessed a major transformation in the global production of chickpea. Not only did global production and yield of chickpea see a very significant rise in these years, but chickpea cultivation expanded to new areas, both within the major chickpea-growing countries and in countries where it had begun to be grown for export (Figure 3.2). The share of chickpea in total area sown with pulses as well as in total production of pulses has increased steadily since the 1990s. The average global yield increased from about 706 kilograms per hectare in 1989–91 to about 957 kilograms per hectare in 2012–14. The bulk of chickpea production continues to be concentrated in countries where it is grown for consumption. In the triennium ending 2013, the last triennium for which data on trade are available, about 12 percent of the global production of chickpea was traded internationally.

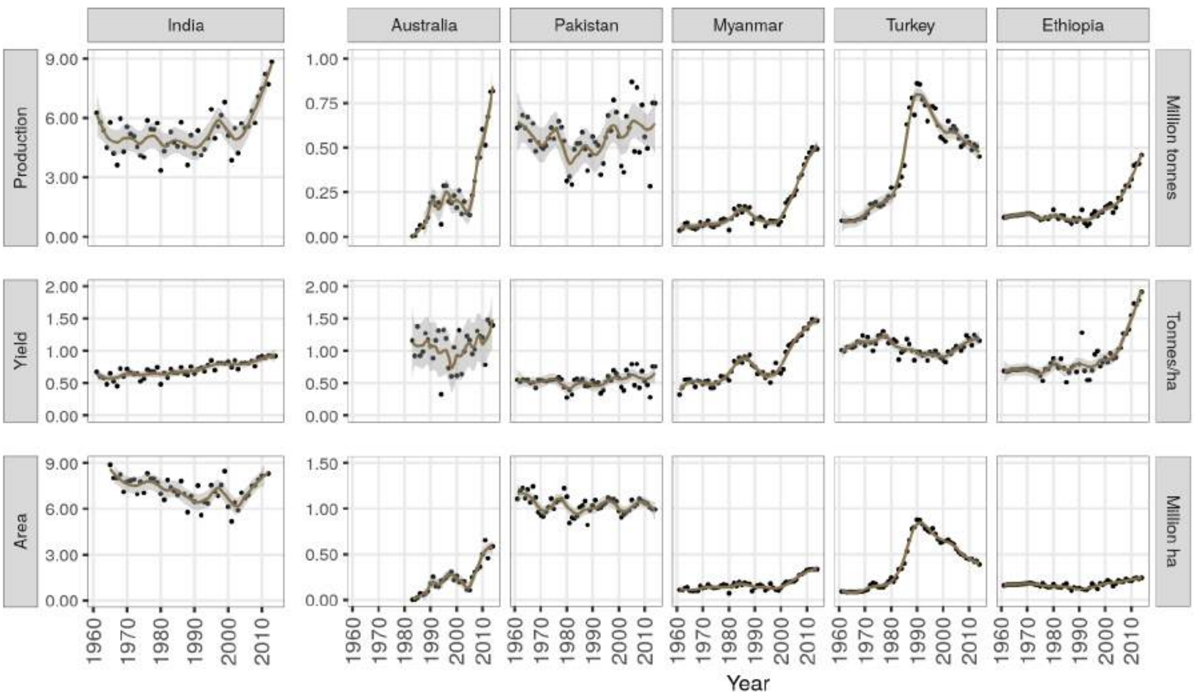
India is by far the largest producer of chickpea in the world with a 67 percent share in global production, followed by Australia (5.9 percent), Pakistan (4.6 percent), Myanmar (3.8 percent), Turkey (3.8 percent), Ethiopia (3.3 percent) and Iran (2.3 percent) (Table 3.1). Chickpea is also produced in Mexico, Canada and the United States. These are countries that boast

Figure 3.1: Chickpea production across different countries, 2012–14



Source: FAOSTAT data, updated using national statistics.

Figure 3.2: Production, yield and area harvested of chickpea, major producing countries, 1961 to 2013



Source: FAOSTAT data, updated using national statistics.

Table 3.1: Average production, yield and area harvested of chickpea, major producing countries, 2012–14

Country	Production (million tonnes)	Yield (kilograms per hectare)	Area harvested (thousand hectares)	Share in world production (percent)
India	8.8	922	9553	67.3
Australia	0.8	1430	538	5.9
Pakistan	0.6	599	996	4.6
Myanmar	0.5	1472	336	3.8
Turkey	0.5	1199	409	3.8
Ethiopia	0.4	1802	236	3.3
Iran	0.3	530	557	2.3
Mexico	0.2	1822	118	1.7
Canada	0.2	2077	73	1.2
United States of America	0.1	1706	86	1.1
World	13.1	957	13664	100.0

Source: FAOSTAT data, updated using national statistics.

substantially high yields of chickpea, ranging from 1,706 kilograms per hectare in the USA to 2,077 kilograms per hectare in Canada, as against relatively lower yields in most of the Asian countries. As shown in Table 3.1, the average yield of chickpea in 2012–14 was only 922 kilograms per hectare in India, 599 kilograms per hectare in Pakistan and 530 kilograms per hectare in Iran. Among the developing countries, Ethiopia and Mexico stood out for high yields.

There are two main types of chickpea, commonly known as *desi* and *kabuli* chickpea.[1] They have different characteristics and their production is concentrated in different parts of the world. *Desi* chickpea has small brown seeds with a pigmented seed coat, and it is mostly grown in relatively warm climates in Asia and Africa. Temperate-region countries – in the Mediterranean belt, North Africa, Europe, South and North America – mainly cultivate *kabuli* chickpea, which has larger round seeds with a light beige-coloured seed coat. In recent decades, the development of new varieties has made the cultivation of both types of chickpea possible in countries like Canada, Australia and India (Ali and Mishra, 2000). Chickpea is sown in the months of September–November in the Indian subcontinent and in some parts of sub-Saharan Africa, whereas in most of the Middle East, Central Asia and North Africa, it is sown in February–March. In Canada, the USA and Australia, chickpea is sown between April and June (see Table 3.2).

There are large gaps between potential and actual yields of chickpea in many chickpea-producing countries. Various kinds of biotic and abiotic stresses are responsible for these yield gaps. Ryan (1997, cited in Toker *et al.*, 2007) attributed an annual shortfall of 6.4 million tonnes in potential global chickpea production to abiotic stresses and about 4.8 million tonnes to biotic stresses. Drought and heat are estimated to be the most significant weather-related causes for less-than-potential yields of chickpea.

1 These names come from India, one of the biggest markets for chickpea, and are now a part of the common parlance of international trade.

Table 3.2: Sowing and harvesting time of chickpea in different countries

Country	Season	Sowing time	Harvesting time
Morocco	Spring	Mid-February – mid-March	June – early July
Tunisia	Spring	Mid-March – mid-April (small areas of winter sowing)	June – early July
Iraq	Spring	Mid-February – mid-March	June
Iran	Spring	Mid-March – mid-April (small areas of winter sowing)	July–August
Israel	Winter	December–February	June
Jordan	Spring	March	July
Jordan	Winter	November–December	Mid-June
Turkey	Spring	February–March (later sowing in highlands)	June
Algeria	Spring	Mid-February – end-March	June – early July
Egypt	Winter	November	April
Ethiopia	Spring–Autumn	September–November	January–February
Sudan	Winter	October–November	June
Syria	Spring	Late February – early May	June – early July
Syria	Winter	December	June – early July
Indian subcontinent	Winter	Late September – November	March–April
Canada	Spring	April–May	July – early August
USA	Spring	April–May	July – early August
Australia	Autumn	May–June	September–December

Note: India and Pakistan are the major chickpea-producing countries in the Indian subcontinent.
Source: Siddique and Krishnamurthy (2014).

Freezing during the vegetative phase, chilling below 10°C during the reproductive phase, salinity, alkalinity, waterlogging and nutrient deficiencies are other important abiotic factors that affect the yield of chickpea globally (Toker *et al.*, 2007).

Among biotic stresses, the greatest damage is caused by pests and diseases like *Helicoverpa*, *Ascochyta* blight and *Fusarium* wilt (Singh *et al.*, 2007) (see Box 3.1). Because of its low levels of resistance to commonly used herbicides, it is not advisable to control weeds through chemical means once the chickpea plant has emerged. Hence manual weeding is resorted to in the developing countries, while in developed countries with large farm sizes, the application of chemical herbicides is restricted to the period either before sowing or immediately after sowing. Weeds have been estimated to result in yield losses of between 23 to 87 percent (Siddique and Krishnamurthy, 2014; Yenish, 2007). Crop rotation and intercropping are essential components of the strategy to deal with the biotic stresses that affect chickpea cultivation.

India, Pakistan and Bangladesh in South Asia have emerged as major importers of chickpea in

Box 3.1: Major diseases and pests affecting chickpea cultivation

Helicoverpa is a major pest that affects chickpea cultivation. No *Helicoverpa*-resistant varieties of chickpea have been developed till date, and chemical control remains the most widely used method for dealing with the pest. Genes that can provide effective resistance to *Helicoverpa* are not available in the chickpea gene pool. Studies have suggested that the introduction of different versions of *Bacillus thuringiensis* (Bt) genes into chickpea can be used to develop varieties that are resistant to *Helicoverpa* (Acharjee and Sarmah, 2013; Acharjee *et al.*, 2010; Lawo *et al.*, 2008; Romeis *et al.*, 2004; Sanyal *et al.*, 2005; Sharma, Stevenson and Gowda, 2005).

Ascochyta blight is a fungal disease caused by *Ascochyta rabiei*. It is widespread in cold and humid climates. Chickpea plants are most susceptible to this disease at the flowering stage; however, the fungal attack, which targets leaves, stems and pods, can occur at any stage of growth of the plant. Many varieties of chickpea have been developed that are partially resistant to *Ascochyta* blight. The disease can also be treated chemically.

Fusarium wilt, a soil and seed-borne disease, is one of the most widespread diseases that chickpea is susceptible to. It is a fungal disease caused by *Fusarium oxysporum f. sp.ciceris*. It can kill young seedlings, or cause wilting or death of adult plants. Modern varieties of chickpea have been developed that are totally resistant to *Fusarium* wilt. However, because of the lack of widespread adoption of these varieties, particularly in less-developed countries, the disease continues to cause substantial crop losses.

Botrytis grey mould (BGM) is another disease that causes heavy yield losses in many chickpea-growing countries.

Dry root rot, another soil-borne disease, is caused either by *Rhizoctonia bataticola* or *Macrophomina phaseolina*. It is prevalent in warmer chickpea-growing regions, and has been reported from countries like India, Australia, Ethiopia, Iran and the USA. Chickpea varieties that are resistant to dry root rot have not been developed so far, and chemical treatment of soil to eradicate this disease tends to be expensive. It is recommended that chickpea should not be grown for a few years in fields infested with dry root rot-causing fungi.

Table 3.3: Annual exports, share in world exports and ratio of exports to production of chickpea, major chickpea-exporting countries, 2011–13

Country	Exports (thousand tonnes)	Share in world exports (percent)	Ratio of exports to production (percent)
Australia	628	40	94
India	241	15	3
Russian Federation	147	9	169
Mexico	126	8	68
Ethiopia	63	4	16
Myanmar	41	3	8
Turkey	24	2	5
World	1567	100	13

Source: FAOSTAT data, updated using national statistics.

Table 3.4: Annual imports, share in world imports and ratio of imports to gross supply of chickpea, major chickpea-importing countries, 2011–13

Country	Imports (thousand tonnes)	Share in world imports (percent)	Ratio of imports to gross supply (percent)
India	384	27	5
Pakistan	185	13	27
Bangladesh	147	11	96
World	1398	100	10

Note: Gross supply refers to production + net imports. Notably, changes in stocks are not accounted for because of lack of separate data for chickpea.
Source: FAOSTAT data, updated using national statistics.

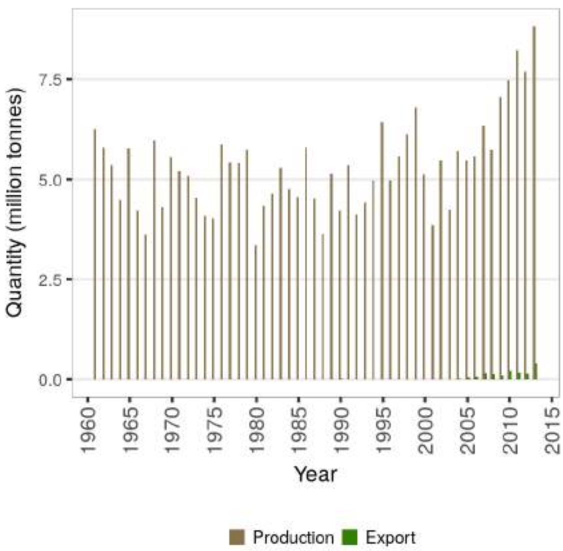
recent years, with an import share of about 27 percent, 13 percent and 11 percent, respectively, in 2011–13 (Table 3.4). In Pakistan, imports accounted for 27 percent of the gross supply of chickpea. Bangladesh, on the other hand, was almost entirely dependent on imports for its chickpea consumption. Since the last two decades, there has been a steady rise in imports of chickpea into Bangladesh, which is mainly due to chickpea production in the country falling from 67,687 tonnes in 1991–93 to 11,000 tonnes in 2001–03 and further to 6,895 tonnes in 2011–13.

India

India is the biggest producer of chickpea in the world, producing about 9 million tonnes annually. It is both a large importer and a large exporter of chickpea. Indian imports of chickpea, which account for about 27 percent of global imports but only 4 percent of gross supply in India, are mainly of the *desi* type. In contrast, Indian exports of chickpea, which constitute about 3 percent of the country's total production, are mainly of *kabuli* chickpea.

Although India is the biggest producer of chickpea and has the largest area under chickpea cultivation globally, the average yield of chickpea in India is low, at only 922 kilograms per hectare.

Figure 3.3: Production and exports of chickpea, India, 1961 to 2013



Source: FAOSTAT data, updated using national statistics.

However, chickpea production in India has undergone a major transformation over the last six decades, and three distinct phases can be identified in the growth of chickpea production during these years.

The 'green revolution' phase

The three decades from the 1960s through the 1980s witnessed a steep decline in the cultivation of chickpea in India. This period of decline coincided with the years of the 'green revolution', when wheat rose to be an extremely remunerative winter crop in irrigated parts of the Indo-Gangetic floodplains. With a large expansion of irrigation, in particular tubewell irrigation, in the Indo-Gangetic floodplains, semi-dwarf varieties of wheat with high yield response to irrigation were widely adopted for the winter crop. Further, the government procured wheat under its minimum support price (MSP) programme, making wheat farming more remunerative and less risky. Thus, due to high yields and assured prices, the average returns from wheat cultivation were considerably higher than that from chickpea cultivation.

Chickpea farmers, in contrast to wheat cultivators, were exposed to the vagaries of weather, plant diseases and pests, and fluctuating markets. Traditional chickpea varieties are extremely sensitive to changes in weather conditions. Given the country's long history of chickpea cultivation, soils in northern India have been infested with wilt-causing fungus. Diseases like *Ascochyta* blight and wilt as well as *Helicoverpa* and other pests were widespread, causing severe damage to the crop (Indian Institute of Pulses Research, 2013). In 1981–83, *Ascochyta* blight assumed epidemic proportions and resulted in massive destruction of chickpea plants in many parts of northwestern India. Destruction of the crop due to wilt has been a regular phenomenon in the states of Punjab, Haryana and Rajasthan (Kumar *et al.*, 2016c).

Table 3.5 presents a comparison of net returns per hectare for chickpea and wheat in the major chickpea-growing states of northern India. The table shows that in 1981–82, the ratio of net returns from cultivation of chickpea to net returns from cultivation of wheat was just 24

Table 3.5: Ratio of average net returns from cultivation of chickpea to average returns from cultivation of wheat, selected north Indian States, 1981–82, 1995–96, 2004–05 and 2013–14 (in kilograms of chickpea equivalents per hectare)

State	1981–82	1995–96	2004–05	2013–14
Haryana	24	43	36	14
Rajasthan	22	22	33	32
Madhya Pradesh	81	44	104	26
Uttar Pradesh	88	71	129	-2

Note: Net returns shown here were computed on paid-out cost plus cost of family labour. The cost estimate used here excludes rental value of owned land and capital. Returns were converted to equivalents of chickpea using farm harvest prices of chickpea.
Source: Data from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

percent in Haryana, 22 percent in Rajasthan, 81 percent in Madhya Pradesh and 88 percent in Uttar Pradesh.

Historically, given the attempts to increase production of food crops in order to do away with large-scale reliance on food imports in exigencies like drought and war, the focus had to remain on crops like wheat and rice where early successes had been obtained in developing high-yielding varieties. Public policy was therefore not geared to address the problem of low returns from chickpea cultivation. However, the decline in chickpea production did receive early attention from agricultural scientists in India.

The All India Coordinated Pulses Improvement Project was instituted in 1967, and was incrementally strengthened during the 1970s and 1980s. Specific research programmes for pulses were initiated under this project, and chickpea especially was a major focus of research. However, the funds allocated for these were limited. Also, since pulses are self-pollinating crops, breeding improved varieties suited to different agro-ecological conditions proved to be difficult and took much longer. Large-scale hybridization programmes were not possible and the focus had to remain on developing improved varieties. Thus, breeding suitable pulse varieties, which are grown mostly in rainfed conditions and face several biotic stresses, was an extremely difficult challenge.

The decade of the 1990s

The trend of decline in the area under chickpea and production of chickpea was arrested in the 1990s. From only 5.6 million hectares in 1991, the area sown with chickpea increased to about 8.4 million hectares by 1998. But this rise in both area and production was short-lived. Towards the end of the decade, with an overall decline in the agricultural growth rate, the area under chickpea and production of chickpea plummeted again; by 2000, the area sown with chickpea was only 5.2 million hectares.

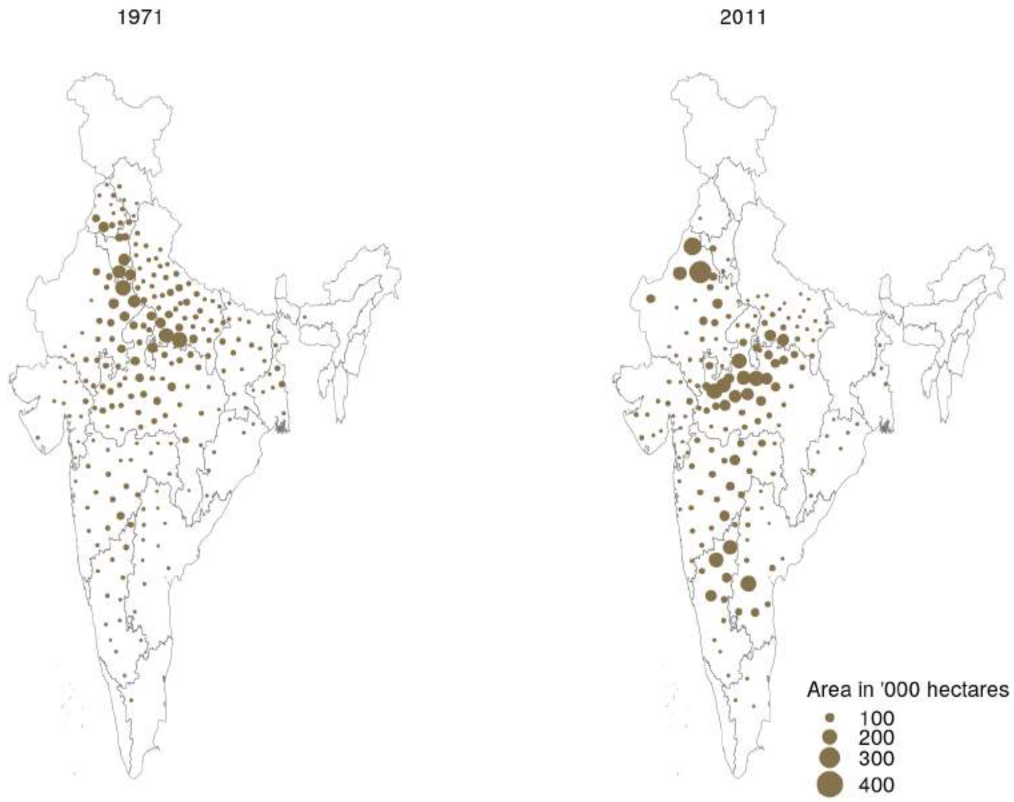
It is, however, noteworthy that significant initiatives were taken in this decade to deal with technological challenges faced by chickpea farmers. In 1990–91, the mandate of the Technological Mission on Oilseeds, which had been extremely successful in strengthening oilseed production in India, was expanded to include pulses. In 1993, a separate All India Coordinated Research Project on Chickpea was established to specifically focus on developing varieties that were suited to different agroclimatic regions, developing shorter-duration varieties, and developing varieties that were resistant to various diseases that afflicted chickpea cultivation.

After 2000: a period of high growth

The third phase – of a sustained rise in the area sown with chickpea and production of chickpea in India – started in the early 2000s. The area under chickpea grew sharply, at 3.4 percent per annum, and the production of chickpea grew at a rate of 5 percent per annum. By 2013, 10 million hectares of land were sown with chickpea and annual production of chickpea reached a record level of over 10 million tonnes.

The scale of recovery of growth of chickpea production in these years was remarkable. Between 1960 and 1980, about 4 million hectares of land had been shifted away from chickpea production, primarily in northern and eastern India. Between 1990 and 2000, an additional 4 million hectares of land, primarily located in

Figure 3.4: Area sown with chickpea, India, 1971 and 2011



Source: Based on ICRISAT (2015) and Surjit (2016).

peninsular India, were brought under chickpea cultivation. The additional area brought under chickpea cultivation in peninsular India between 1991 and 2013 was larger than the total area sown with chickpea in 2013 in all countries of the world other than India.

At the same time, it needs to be noted that chickpea production in the northern Indo-Gangetic floodplains has remained less remunerative than wheat cultivation. As seen in Table 3.5, in 2013–14, the ratio of net returns from cultivation of chickpea to net returns from cultivation of wheat was just 14 percent in Haryana, 32 percent in Rajasthan and 26 percent in Madhya Pradesh. Average returns from chickpea cultivation were negative in Uttar Pradesh in 2013–14. Consequently, agriculture in the irrigated parts of the Indo-Gangetic floodplains, particularly in the northwestern states, remained dominated by a rice–wheat cropping cycle. The expansion of chickpea production during these years took place in the semi-arid parts of central and southern India (Ali, Kumar and Singh, 2003; Gowda *et al.*, 2009; Rimal *et al.*, 2015; Tuteja, 2006). The change in concentration of area under chickpea cultivation from northwestern, eastern and central India to central and southern India is seen clearly in Figure 3.4.

Over the last three decades, a large number of chickpea varieties that are resistant to diseases, in particular to *Fusarium* wilt and partially to *Ascochyta* blight, have been developed by the All India Coordinated Research Project on Chickpea. This has been an outcome of strong collaborative efforts of the Indian Council of Agricultural Research (ICAR), state agricultural universities, and Consultative Group on International Agricultural Research (CGIAR) institutions like the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Production of breeder, foundation and certified seeds takes place through a network of ICAR research and field stations, state-level agricultural universities and Departments of Agriculture of state governments. Figure 3.5 shows that the number of improved chickpea varieties deployed in India and the production of breeder seeds of these varieties doubled between 1999–2000 and 2014–15.

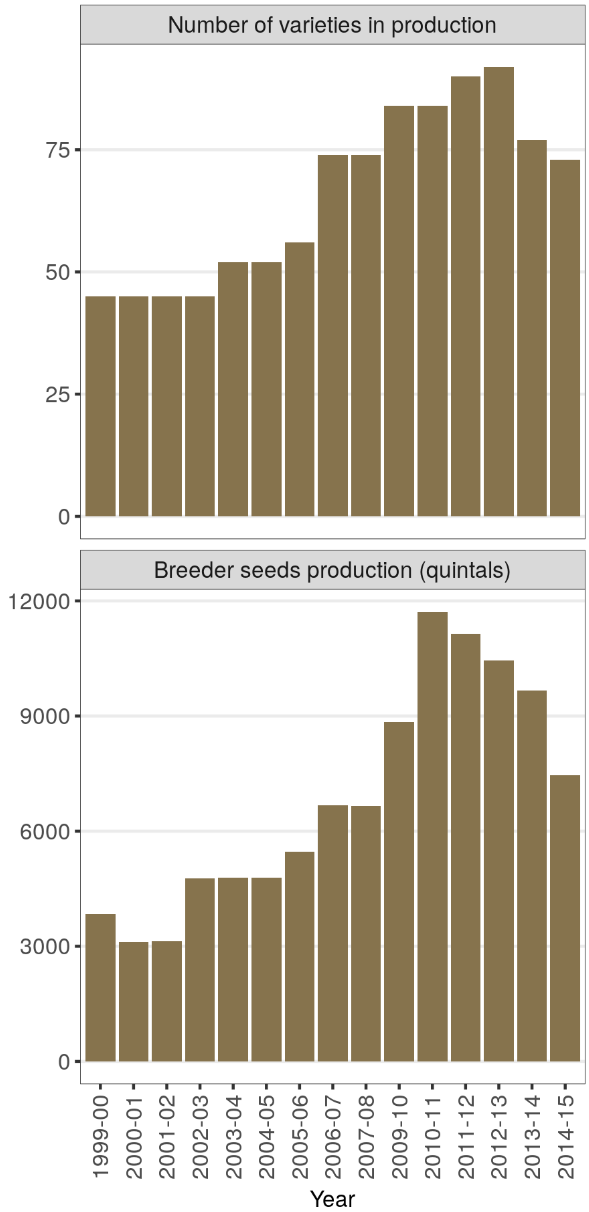
Although considerable gaps remain in the adoption of improved varieties of seeds in different parts of the country, in some of the new chickpea-growing areas like Andhra Pradesh and Telangana, almost all the land under chickpea is sown with improved varieties.

Traditionally, a large part of the chickpea-growing areas in central and southern India receive low to medium rainfall, concentrated in the months June to September. Winters are short and the minimum temperature in the coldest months (December–January) is about 15°C. With very little irrigation potential, agriculture remains primarily rainfed, and, at best, receives supplementary irrigation. Until recently, long-duration millets, oilseeds, cotton or pulses were cultivated on most of the land in this region in the *kharif* season, with sowing done between June and August, crops harvested between December and March, and much of the land left fallow for the rest of the year.

Cultivation of chickpea in the semi-arid parts of central and southern India was made possible because of the development of heat-resistant, short-duration (95–110 days rather than 160–170 days) varieties. A study of the southern state of Andhra Pradesh found that cultivation of short-duration chickpea had replaced sorghum, sunflower, coriander and groundnut (Bantilan *et al.*, 2014). Further, adoption of short-duration chickpea was facilitated by the development of varieties grown in the *kharif* season, which allowed early sowing. ICCV 2, released in 1991, was the first short-duration variety of chickpea with a maturing period of 110 days. This was followed by the development of other short-duration varieties like JG 11, KAK 2, Virat, JG 74, JGK 1 and BGD 72, with a maturity period between 95 to 100 days (Chaturvedi and Dua, 2001).

It is also noteworthy that while diseases like *Ascochyta* blight and *Fusarium* wilt were widespread in their occurrence in the cold, humid climate of the Indo-Gangetic floodplains, which were traditional chickpea-growing areas,

Figure 3.5: Number of improved chickpea varieties and quantity of breeder seeds used in chickpea cultivation, India, 1999–2000 to 2014–15



Source: Data from *Annual Reports* of the All India Coordinated Research Project on Chickpea, various issues.

the semi-arid areas of central and southern India do not face this problem. Because chickpea cultivation is relatively recent in these regions, the incidence of soil fungus that causes *Fusarium* wilt is also much less here. With greater adoption of improved varieties and lower levels of biotic stress, yields in the new chickpea-growing areas of central and southern India are considerably higher than in northwestern India where chickpea production was concentrated earlier (Figure 3.4).

Improved, disease-resistant, short-duration cultivars of high-value, large-seeded *kabuli* chickpea have been adopted in the states of Andhra Pradesh, Madhya Pradesh, Maharashtra and Karnataka. This has led to India achieving not only self-sufficiency in production, but also increased exports of *kabuli* chickpea.

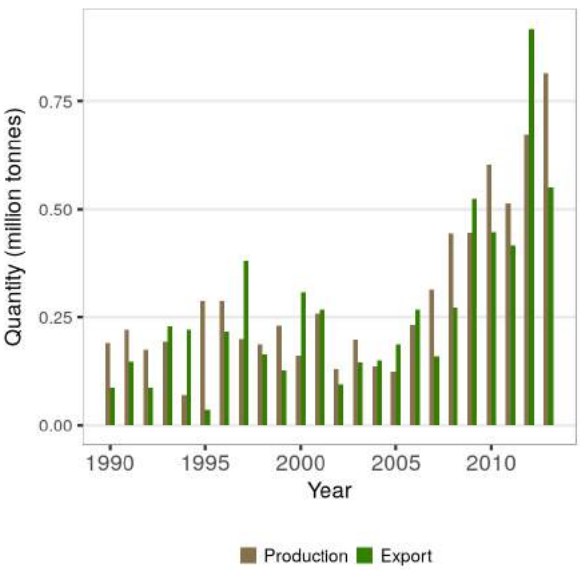
Australia

Chickpea production started in Australia in the late 1970s in response to demand from the Indian subcontinent. Owing to a sharp rise in production since the mid-2000s, Australia has emerged as the second largest producer of chickpea after India and the biggest exporter of chickpea in the world. In 2012–14, 0.51 million hectares of land in Australia were under chickpea. With an average yield of about 1,400 kilograms per hectare, which is one of the highest among all major chickpea-producing countries, Australia had an annual production of 0.8 million tonnes in 2012–14. About 95 percent of the chickpea produced in Australia is of the *desi* variety.

Australia produces chickpea mainly for exports. During 2011–13, the latest years for which data on exports are available, 94 percent of the chickpea produced in Australia was exported. Chickpea exports from Australia in 2011–13 accounted for about 40 percent of world exports of chickpea.

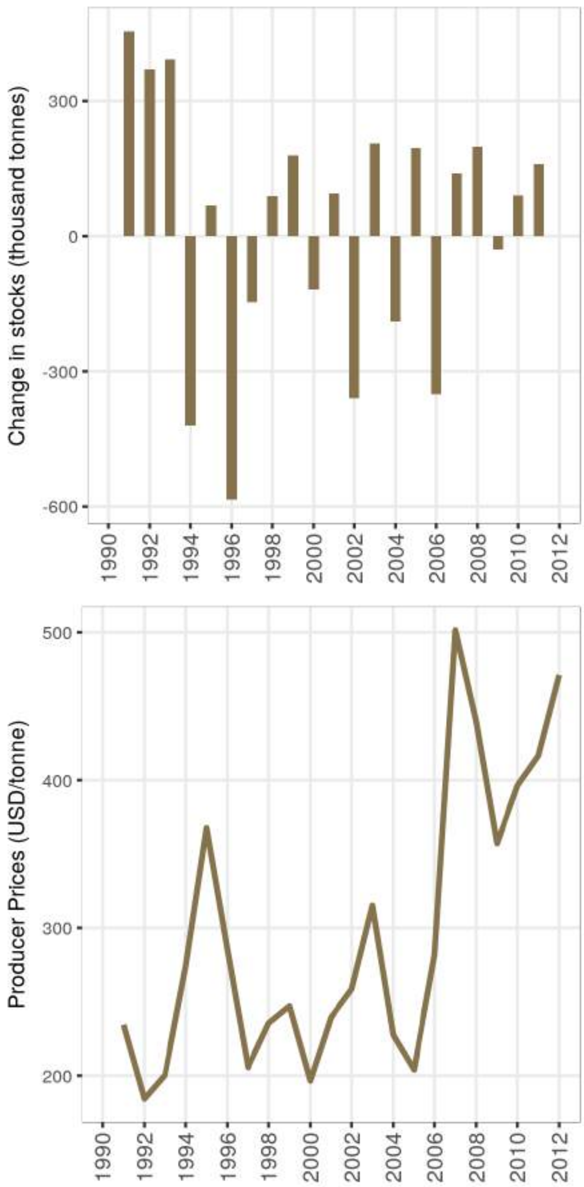
Chickpea is grown in Australia in varied agro-ecological environments, which can be classified into four regions: northeastern tropical, northeastern sub-tropical, southeastern

Figure 3.6: Production and export of chickpea, Australia, 1990 to 2013



Source: FAOSTAT data.

Figure 3.7: Producer prices of chickpea and net change in stocks of pulses, Australia, 1990 to 2012



Source: FAOSTAT data.

Mediterranean and western Mediterranean (Knights *et al.*, 2009). These regions differ from each other in terms of rainfall distribution and temperature, and consequently in the duration of the chickpea-growing season. The soils of these regions are also different.

The northeastern tropical region receives highly variable summer rainfall. The growing season here is limited to 100–120 days because of high temperatures and terminal drought. *Desi* varieties of chickpea are grown here. The northeastern sub-tropical region receives less rainfall as compared to the northeastern tropical region. This region also has lower temperatures and shorter photo-periods, which result in a longer growing season that ranges between 150 to 170 days. Southern parts of the country – New South Wales, Victoria and South Australia – receive rainfall mainly during the winter, and have a longer growing season, 200–220 days, than other regions of the country. The longer growing season also results in higher yields in these parts. In the western Mediterranean region, with relatively low seasonal rainfall and relatively high temperatures, the growing season ranges between 180 and 200 days.

With the expansion of chickpea production in Australia since the 1980s, chickpea has become an integral component of crop rotation. However, due to the prolonged cultivation period of legume crops, diseases and pests have also become pervasive in the country. An outbreak of *Ascochyta* blight in the mid-1990s, which assumed epidemic proportions in many regions, caused a sharp decline in chickpea production: from about 0.3 million tonnes produced annually in 1995, production came down to as low as 0.12 million tonnes in 2005. It was only with the release of varieties resistant to *Ascochyta* blight and the adoption of prophylactic management practices that production levels were restored (Berger and Turner, 2007; Knights *et al.*, 2009). Diseases like nematodes and pests like *Helicoverpa* also cause considerable damage to the chickpea crop. Although significant research has been done to develop varieties resistant to these diseases and pests, in Australia as well as in other chickpea-producing countries, farmers currently have to rely on the use of insecticides in dealing with these problems (Knights *et al.*, 2009).

Australia has considerable capacity for maintaining stocks of chickpea. With silos at the farm level as well as storage facilities of major exporting companies, the country can hold huge stocks and thereby handle price fluctuations. Figure 3.7 shows that Australia made a net addition to stocks of peas (including chickpea and dry pea) in excess of 100,000 tonnes in some years, and disposed of stocks in excess of 100,000 tonnes in other years. While a one-to-one relationship with actual prices cannot be seen in many years, the inverse relationship between prices and change in stocks stands out clearly. In 2005 and 2009, for example, a drop in prices was dealt with by accumulation of stocks. On the other hand, with rising prices in 2002, 2006 and 2010, stocks dropped. Like most pulses, chickpea is highly susceptible to storage pests like bruchids in warm and humid weather. Unlike cereals, chickpea needs to be stored in silos with controlled temperatures and humidity. The capacity to stock large quantities of chickpea gives Australian farmers and exporters an advantage that small producers in developing countries do not have.

Myanmar

Myanmar is another country that has seen a sharp rise in chickpea production, particularly since the late 1990s (Figure 3.8). Annual production of chickpea in Myanmar, which was about 0.1 million tonnes in the 1990s, increased to about 0.5 million tonnes by 2012–14. Chickpea is grown in Myanmar for domestic consumption as well as for exports. According to the available data, exports in recent years accounted for a little less than 10 percent of total domestic production. In Myanmar, *desi* chickpea is consumed as both split grain and as flour, while the *kabuli* variety is mainly grown for exports.

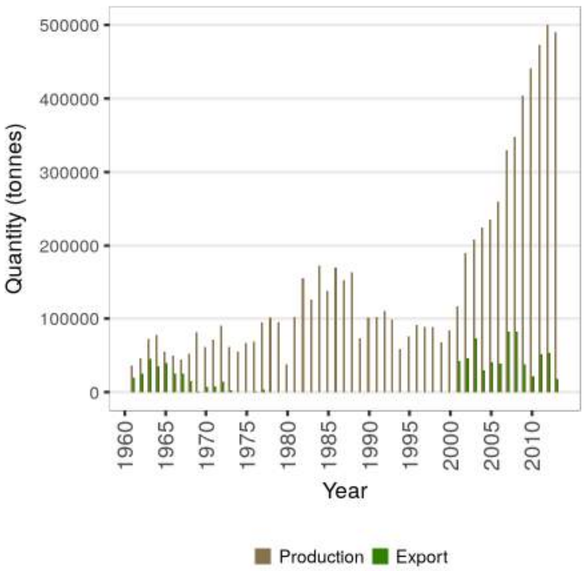
The rise in chickpea production in Myanmar since the 1990s was primarily the result of an increase in chickpea yields, which doubled from about 726 kilograms per hectare in 1989–91 to 1,472 kilograms per hectare in 2012–14 (Figure 3.2).

Among the developing countries where chickpea is cultivated, Myanmar (along with

Ethiopia) is noteworthy for its success in widespread adoption of improved varieties. New varieties have been released in the country from the germplasm/breeding lines supplied by ICRISAT. Yezin 4 (ICCV 88202) and Yezin 6 (ICCV 92944) are the main *desi* chickpea types grown here, while Yezin 3 (ICCV 2) and Yezin 8 (ICCV 97314) are the main *kabuli* varieties (Win, Shwe and Gaur, 2014). Table 3.6 shows that improved varieties were sown on 97.4 percent of the total area under chickpea in Myanmar in 2014–15. Yield improvement on account of improved varieties has been marked. The average yield of chickpea on land sown with improved varieties was 1,479 kilograms per hectare, while the average yield on land sown with local varieties was only 929 kilograms per hectare.

It needs to be pointed out that although improved varieties of chickpea have been adopted almost universally in Myanmar, the seed replacement rate continues to be low. In 2014–15, less than 3 percent of the land under chickpea was planted with freshly acquired certified seed. Improving seed replacement rates requires an increase in the production of certified seeds as well as a major expansion of the agricultural extension system for the distribution of new seeds.

Figure 3.8: Production and exports of chickpea, Myanmar, 1961 to 2013



Source: FAOSTAT data.

Table 3.6: Share of different varieties in total area sown with chickpea and yields of different varieties, Myanmar, 2014–15

Variety	Share in total area sown (percent)
Yezin 3 (ICCV 2)	36.5
Yezin 6 (ICCV 92944)	18.9
Yezin 4 (ICCV 88202)	16.2
Yezin 8 (ICCV 97314)	17.7
Kayarchi	6.8
Yezin 5 (ICCV 3)	1.3
Shwenilonegyi	0.0
Local varieties	2.6
Total	100 (378060 ha)

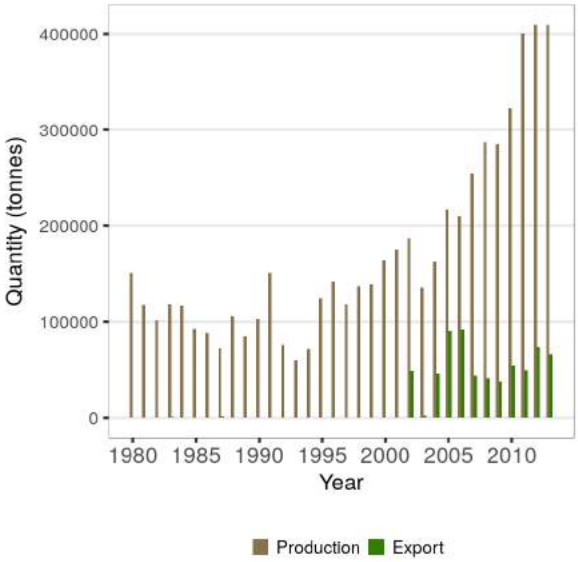
Source: Data from the Department of Agriculture, Government of Myanmar.

Ethiopia

Ethiopia is the largest producer of chickpea in Africa, and the sixth largest producer globally (Table 3.1). In 2012–14, it accounted for about 60 percent of total chickpea production in Africa. Chickpea production in Ethiopia is concentrated in two regions: Amhara and Oromia. In 2012, these two regions accounted for 93 percent of the country's total chickpea production. Since the 2000s, chickpea production in Ethiopia has been rising continuously, mainly on account of a remarkable growth in yields.

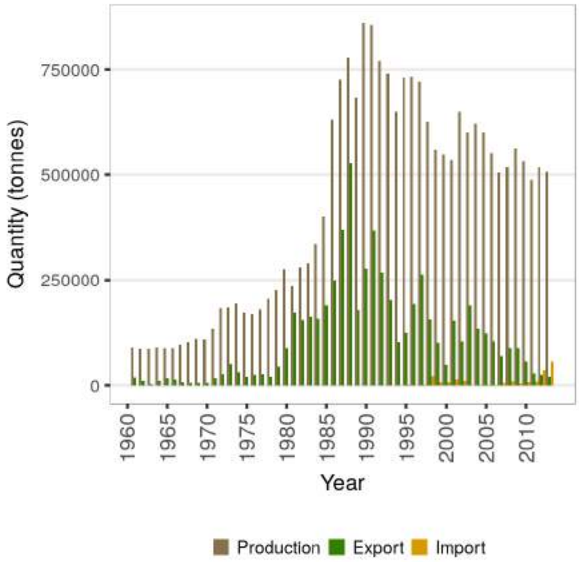
The increase in chickpea yields has been driven mainly by the introduction of improved varieties. Collaborative efforts of the International Center for Agricultural Research in the Dry Areas (ICARDA), ICRISAT and the Ethiopian Institute of Agricultural Research (EIAR) have resulted in the development of various improved high-yielding cultivars of chickpea. Yigezu, Yirga and Aw-Hassan (2015) report that nineteen improved varieties based on ICRISAT and ICARDA breeding material were released in Ethiopia between 1980 and 2010.

Figure 3.9: Production and exports of chickpea, Ethiopia, 1980 to 2013



Source: FAOSTAT data.

Figure 3.10: Production, exports and imports of chickpea, Turkey, 1961 to 2013



Source: FAOSTAT data.

Adoption of improved chickpea varieties rose from 30 percent in 2006–07 to about 80 percent by 2013–14 (Ojiewo, 2016). *Arerti*, an early-maturing variety, is one of the leading improved varieties of chickpea in Ethiopia (Yigezu, Yirga and Aw-Hassan, 2015). With the availability of suitable cultivars of *kabuli* chickpea, production of high-value *kabuli* for exports has increased. Currently, *kabuli* accounts for about one-third of the total area sown with chickpea in Ethiopia.

This remarkable increase in production has been used mainly for domestic consumption. In 2011–13, only about 16 percent of the total chickpea produced in Ethiopia was exported (Table 3.3).

Turkey

Turkey, the country to which the origin of chickpea can be traced, is an important producer of the *kabuli* variety. Since chickpea is an important part of Turkish food, there is substantial domestic demand for it. At 6.65 kilograms per capita per annum, the average national consumption of chickpea in Turkey is higher than in any other country in the world (Yadav *et al.*, 2007b).

Chickpea is sown in Turkey in spring, from late March to mid-April, and it is harvested in the months of May–June (Berrada, Shivakumar and Yaduraju, 2007). Until the 1980s, Turkey produced chickpea for both domestic consumption and exports. In the decade of the 1980s, a period of high growth of chickpea production in the country, over 60 percent of global exports of chickpea came from Turkey. During this period, the Turkish government targeted an expansion of area under chickpea cultivation in order to utilize land left fallow after cereal production.

However, while the 1980s witnessed a spectacular rise of chickpea cultivation in Turkey, the next two decades saw an equally spectacular fall. The area sown with chickpea fell from 0.85 million hectares in 1989–91 to 0.4 million hectares in 2012–14. Correspondingly, the production of chickpea fell from 0.8 million tonnes in 1989–91 to 0.5 million tonnes in 2012–14.

This decline in production was driven almost entirely by a decline in chickpea exports. With a turnaround in chickpea production in India and a rise in export-oriented production of chickpea in Australia and Myanmar, Turkey's exports became non-competitive from the early 1990s, and there was a sharp fall in both production and exports of chickpea. Data for recent years show that Turkey accounts for less than 2 percent of world exports of chickpea and has become a net importer of chickpea.

Knights *et al.* (2007) attribute the decline in chickpea cultivation in Turkey to withdrawal of the agricultural incentive system and reduction of input subsidies. Reddy *et al.* (2007) compared the cost and profitability of chickpea production in various countries, and pointed out that Turkey faced competition from the USA, Canada and Mexico. *Kabuli* chickpea produced in North America was larger in size and therefore preferred over Turkish chickpea. Chickpea production in Turkey was small-scale, characterized by low levels of mechanization, poor marketing infrastructure and frequent crop damages because of *Ascochyta* blight. Given the much larger scales of production in the USA and Canada, and considerable economies of scale due to both mechanization and agronomic practices, the cost of production in these countries was found to be considerably lower than in Turkey. Further, a wide yield gap between chickpea and wheat in Turkey made wheat a more profitable crop for farmers.

Other Chickpea-Producing Countries

Pakistan, Russia and Mexico also have significant production of chickpea. Chickpea production in Pakistan is characterized by low yields (599 kilograms per hectare in 2012–14) and the area under cultivation here has remained stagnant at about 1 million hectares. In the case of Russia, there has been a steep rise in the volume of chickpea exports since 2010, reaching an average of about 147,000 tonnes in 2011–13. Mexico, which was one of the biggest players in terms of exports in the early 1970s, has witnessed a fall in its exports over the last decade, with its average share in total world exports falling to 8 percent in 2011–13.

Cost of Production and Returns from Chickpea Cultivation

Data on cost of production and margins in chickpea cultivation are available for Australia, India, Myanmar and Turkey, and are summarized in Table 3.7. To render the data, which are given in local currencies, comparable, the cost and margins were converted to equivalent kilograms of chickpea using corresponding producer prices. For Australia, these data are based on average returns for farms in the medium rainfall zone. For India, the estimates are weighted averages for major chickpea-growing states, for which data are available from official cost of production surveys. For Myanmar, these data come from a recent survey of four states (Zorya *et al.*, 2016). This survey, based on detailed sampling in the four states, covered relatively better developed and more accessible villages, which were expected 'to be the most economically active, receive more public services, have better access to markets, and represent long-established production areas with better soils and production environments'. The survey report pointed out that the Myanmar survey represents 'production economics of better-performing farms' and 'profitability of agricultural production when adequate level of inputs and more modern technologies are used'. For Turkey, the data come from a report based on estimates of the Agricultural Directorate in Adana region in southern Turkey (Ørum *et al.*, 2009).

The summary of all these statistics presented in Table 3.7 shows that per hectare gross margins are highest in Australia and lowest in Myanmar. In Australia, gross margins are about 57 percent of the total value of output. In India, Myanmar and Turkey, all countries producing chickpea predominantly on small to medium-sized family farms, the gross margins amount to about 34–38 percent of gross value of output. In absolute terms, an Australian farmer who grows chickpea gets a margin of 7.4 quintals per hectare over variable costs, while the margins of farmers in India, Myanmar and Turkey vary between 3 to 4 quintals per hectare.

The farms in all these countries, including Australia, are predominantly family farms. However, there is a great asymmetry in the size of the farms. According to data from the 2010–11 Agricultural Census, the average cultivated area of a grain-producing farm in Australia was 1,490 hectares. In contrast, the median landholding

Table 3.7: Gross value of output, costs and gross margin for chickpea production, India, Myanmar, Turkey and Australia (equivalent kilograms of chickpea)

Output, costs and gross margin	India* (2013–14)	Myanmar (2016)	Adana, Turkey (2009)	Australia (2015)
Output				
Gross value of output (USD per hectare)	534	401	1117	518
Yield (kilograms per hectare)	1009	902	1000	1300
Producer price (USD per kilogram)	0.5	0.44	1.12	0.40
Variable costs				
Seed	113	151	174	119
Fertilizers and manure	55	92	106	87
Plant protection chemicals and inoculants	21	24	30	242
Irrigation	44		–	–
Machinery and draught animals	154	114	94	76
Hired labour	127	127	150	–
Family labour	129	74	30	–
Interest on working capital	16	9	49	
Insurance	–	–	–	13
Levies	–	–	–	26
Miscellaneous	0.6		28	
Total variable costs	660	590	661	563
Gross margins at farm gate			0	
Gross margin	407	312	339	737
Gross margin (USD per hectare)	204	139	379	294

*Gross value of output includes value of crop byproducts.
Source: Estimates and data from CACP (2015); Government of South Australia (2015); Ørum *et al.* (2009); and Zorya *et al.* (2016).

in India was only about 0.6 hectare. The huge disparity in farm sizes and variations in per hectare margins imply a massive inequality of total farm incomes between family farmers in countries with large industrialized production of chickpea and countries where chickpea is cultivated on small holdings.

It is noteworthy that the cost of seeds in chickpea production is high because of high seed-rate requirements. The optimal seed rate for chickpea is about 100 kilograms per hectare. In countries where seed selection is poor, germination rates are low and seeds are broadcast, a higher seed rate is used. In Australia, improved seed varieties are purchased and used, which results in high seed costs despite a lower seed rate. As shown in Table 3.7, the cost of seed was lowest in India (equivalent to 113 kilograms of chickpea produce) and highest in Turkey (equivalent to 174 kilograms of chickpea produce).

Use of plant protection chemicals, mainly herbicides, is much higher in Australia than in the other countries; plant protection chemicals constitute about 43 percent of the variable costs in Australia. In countries with small family farms where weeding is done manually, expenditure on plant protection chemicals is only 3–4 percent of total variable costs. Herbicides used as a substitute for tilling and economies of scale in the deployment of machines on large farms result in lower costs of machines in Australia than in other countries. Most smallholder producers in India do not own all the machines that are deployed and depend on rental markets, which further raises the cost of deployment of machinery on small family farms.

Conclusions

Chickpea accounted for about 17 percent of global production of pulses in 2012–14. Global trends have shown a remarkable rise in chickpea production over the last fifteen years. This was because of the development of improved varieties that are high-yielding, short-duration, heat-resistant and resistant to some of the major diseases that affect chickpea. The development of such varieties has made cultivation of chickpea possible in regions of the world where it was not a part of traditional cropping systems. The adoption of new varieties and modern agronomic practices in both traditional chickpea-growing countries like India and new chickpea-producing countries like Myanmar and Australia has resulted in accelerated growth of chickpea production.

In most countries, returns from cultivation of chickpea, a cool season legume, are lower than for crops like wheat, barley or rapeseed. Consequently, chickpea production in South Asia and Africa remains confined to unirrigated areas. While the irrigated areas in these regions have shifted to more profitable crops, the availability of suitable varieties has made chickpea a viable crop in unirrigated areas as well as areas where chickpea was not traditionally grown.

In Australia, although the margins in chickpea production are lower than in wheat, chickpea has been widely adopted as a break crop in the multi-year crop cycle because of its benefits in terms of maintaining soil fertility. Also, with the adoption of improved, disease-resistant varieties and modern agronomic practices, the average yields of chickpea in Australia are high. High output and economies of scale make the average gross margins from chickpea production much higher in Australia than in countries characterized by smallholder cultivation of chickpea.

In countries where chickpea is primarily produced on small holdings, lack of adoption of improved varieties and modern agronomic practices continue to adversely affect yields. Lack of resistance to *Helicoverpa* continues to be a major problem, and *Ascochyta* blight, *Botrytis* grey mould and dry root rot are causes of substantial yield losses.

Apart from technological challenges, there are various economic and policy-level issues that need to be dealt with for further expansion of chickpea production. In countries with smallholder production, extension work is needed to educate farmers about modern agronomic practices, particularly to enable them to deal with pests and diseases. The profitability of chickpea is lower than that of cereals like wheat and barley, because of which cultivators with access to irrigation prefer to grow these latter crops. Another challenge faced by developing countries in chickpea production is considerable post-harvest losses because of poor storage infrastructure.

PULSES OF PHASEOLUS AND VIGNA GENERA

Prachi Bansal, Vikas Rawal, Vaishali Bansal

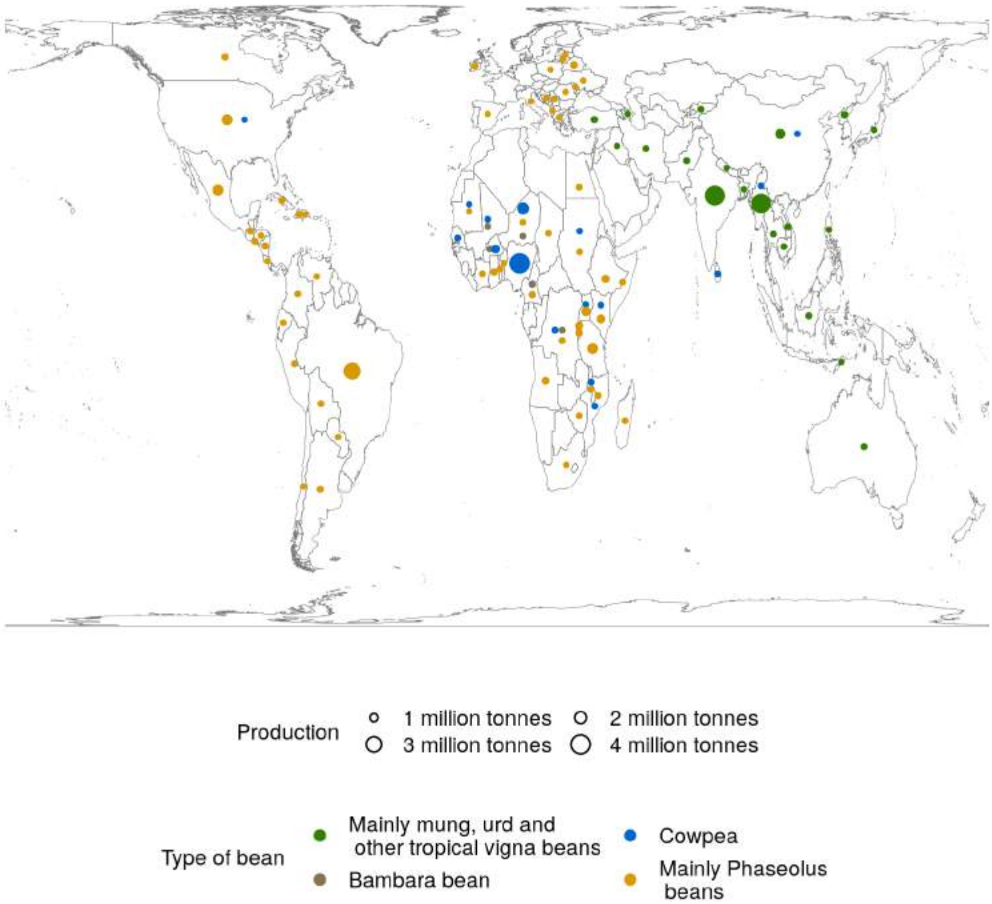
Introduction

This chapter discusses legumes of two genera: *Phaseolus* and *Vigna*. Pulses belonging to these genera account for about 41 percent of the global production of pulses. Cross-country data on several *Phaseolus* and *Vigna* pulses are provided in FAOSTAT under a single category called 'dry beans', which includes common bean (*Phaseolus vulgaris*), lima or butter bean (*Phaseolus lunatus*), scarlet runner bean (*Phaseolus coccineus*), tepary bean (*Phaseolus acutifolius*), adzuki bean (*Vigna angularis*), mung bean (*Vigna radiata*), urd bean (*Vigna mungo*), rice bean (*Vigna umbellata*) and moth bean (*Vigna aconitifolia*) (see http://www.fao.org/es/faodef/fdef04e.htm#4.02). It must be noted here that *Vigna* pulses that are now included in the FAOSTAT category of 'dry beans' were earlier classified as belonging to the *Phaseolus* genus along with other *Phaseolus* pulses. On the other hand, two important pulses that have always been classified as belonging to the *Vigna* genus, namely cowpea and bambara bean, are not included in the FAOSTAT category of 'dry beans'. For these reasons of 'mixed' classification, it is not possible to analyse global production trends separately for *Phaseolus* and *Vigna* pulses. In view of this limitation, this chapter presents production trends for all pulses of *Phaseolus* and *Vigna* genera by combining the FAOSTAT category of dry beans with cowpea and bambara bean. It then goes on to separately discuss the production conditions of various pulses of these two genera in the major producing countries by combining the FAOSTAT data with national statistics.

Pulses of these two genera are grown widely across the world (Figure 4.1). Pulses of the *Phaseolus* genus are mainly produced in the Americas and Africa. Of these, the common bean, or *Phaseolus vulgaris*, is one of the most important pulse crops in terms of global scale of production. Pulses of the *Vigna* genus, primarily cowpea (*Vigna unguiculata*), mung bean (*Vigna radiata*), urd bean (*Vigna mungo*), adzuki bean (*Vigna angularis*) and moth bean (*Vigna aconitifolia*), are mainly produced in Asia and Africa.

In 2012–14, pulses of these two genera

Figure 4.1: Production of pulses of *Phaseolus* and *Vigna* genera across countries, 2012–2014 (million tonnes)



Source: FAOSTAT data, updated using national statistics.

accounted for 50.37 percent of the total area sown with pulses and about 41.3 percent of pulses produced globally. As shown in Table 4.1, the total production of *Phaseolus* and *Vigna* pulses in 2012–14 was 32 million tonnes. Nigeria, Myanmar, India and Brazil were the top four countries of the world producing *Phaseolus* and *Vigna* pulses, but each of these countries produced different types of pulses of these two genera. Nigeria mainly produced cowpea, while Myanmar and India were frontrunners in the production of mung and urd beans. India was also the only country that produced significant quantities of moth bean. Niger, the United States of America (USA), Tanzania and Mexico had annual production figures of over 1 million tonnes each of *Phaseolus* and *Vigna* pulses. Brazil, the USA and Mexico were leading producers of different types of common bean, including pinto bean, black bean, white bean, red kidney bean, cannellini bean, borlotti bean, haricot bean and flageolet bean.

This chapter separately discusses trends in production of pulses of the *Phaseolus* and *Vigna* genera, and also the dynamics of change in different parts of the world for each major pulse crop.

Common Bean

Common bean (*Phaseolus vulgaris*) is one of the most important pulses cultivated and consumed the world over. FAOSTAT does not provide separate data on common bean and therefore it is not possible to examine global trends in its production. It has been estimated, however, that about 12 million tonnes of common bean are produced annually across the world. This includes different types of common bean, which are of distinct colours, sizes and other attributes, grown in different parts of

Table 4.1: Average production, yield and area harvested of *Phaseolus* and *Vigna* pulses, major producing countries, 2012–14

Country	Production (million tonnes)	Yield (kilograms per hectare)	Area harvested (thousand hectares)	Share in world production (percent)
Nigeria	4.0	1106	3592	12.5
Myanmar	3.8	1353	2827	12.0
India	3.8	406	9400	12.0
Brazil	3.0	1031	2903	9.4
Niger	1.6	304	5156	4.9
United States of America	1.3	2051	644	4.2
Tanzania	1.3	928	1401	4.1
Mexico	1.2	731	1665	3.8
China	1.1	1186	920	3.4
Uganda	0.9	1302	697	2.9
World	31.8	762	41712	100.0

Source: FAOSTAT data, updated using national statistics.

Box 4.1: Different types of common bean

There are many different types of common bean (*Phaseolus vulgaris*) with marked differences in colour, size, texture and taste.

Pinto bean: These are brown, oval-shaped, speckled beans. Their earthy flavour and powdery texture make them a staple in Mexican and Hispanic diets. In Africa, these beans are often eaten with potatoes.

Carioca bean: These beans, with khaki stripes on a beige seed coat, are the most important beans consumed in Brazil.

Black bean: Also called turtle beans, these beans are oval-shaped with a small white spot and are sweet-flavoured. They are mainly consumed in Brazil and Mexico.

Navy bean: Also known as peabean, white peabean, haricot or pearl haricot bean, these came to be known as navy beans because they used to be served to sailors on American ships. They are small, white and oval-shaped with a smooth texture.

Great northern bean: These are medium-sized, oval-shaped beans with a mild flavour. They are used in North American cuisine, in soups and casseroles.

Borlotti bean: Also known as cranberry bean, these are large, beige-coloured, plump beans with red markings.

Cannellini bean: Also known as *fasolia* or Italian white kidney bean, these are small, kidney-shaped and white in colour.

Red kidney bean: Known as *rajma* in northern India and Pakistan, these are popular in South American diets. They are kidney-shaped, could be light red or dark red in colour, and have a soft texture.

Flageolet bean: These are small, kidney-shaped beans with a mint-green colour.

the world. Box 4.1 lists the main types of common bean and their broad characteristics.

Brazil, the USA and Mexico are the three largest producers of common bean in the world, contributing about 5.6 million tonnes of global annual production. While the USA is a net exporter, Mexico and Brazil produce mainly for domestic consumption. Africa too is a substantial producer of common bean: in the triennium ending 2014, the annual production of common

Table 4.2: Average annual production, yield and area harvested of common bean, major producing countries in Africa, 2012–14

Country	Production (million tonnes)	Yield (kilograms per hectare)	Area harvested (thousand hectares)	Share in African production (percent)
Tanzania	1.1	945	1177	18.9
Uganda	0.9	1334	672	15.2
Kenya	0.7	611	1064	11.0
Ethiopia	0.5	1417	339	8.1
Rwanda	0.4	915	471	7.3
Africa	5.9	794	7430	100.0

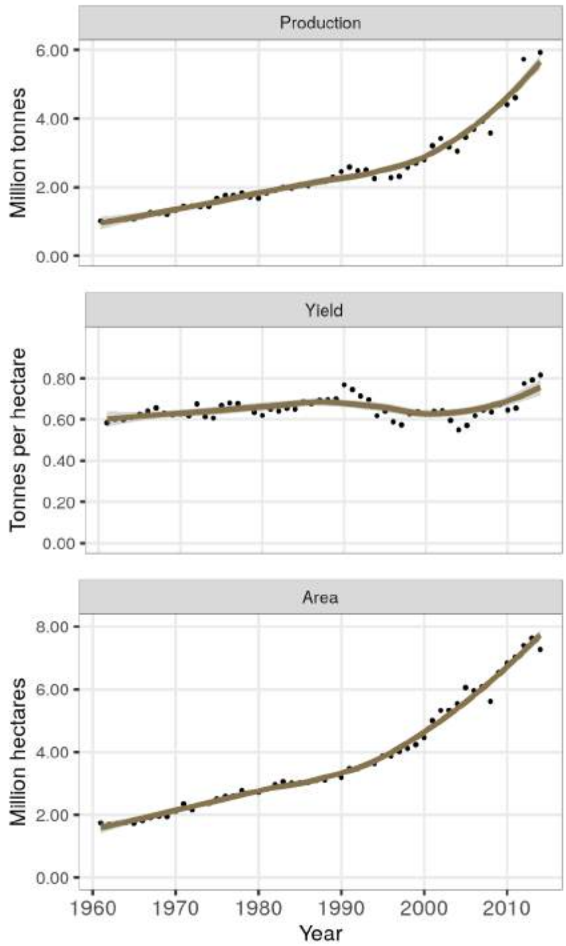
Source: FAOSTAT data.

bean in Africa was 5.9 million tonnes, accounting for 32 percent of the total pulses produced in Africa.[1] Production of common bean in Africa is mainly concentrated in the eastern and central regions; Tanzania, Uganda, Kenya, Ethiopia and Rwanda are the major producing countries, together accounting for 60 percent of Africa's total production. Common bean produced in African countries is mostly for domestic consumption. In 2011–13, only about 7 percent of common bean produced here was exported, most of it to other African countries (Table 4.7).

Brazil

Brazil is the largest producer of common bean in the world. In 2015, 3.08 million tonnes of common bean were produced here. Brazil produces beans mainly for domestic consumption, and in 2013 the average per capita consumption of beans here was 16 kilograms. Carioca bean and black bean are the two main types of common bean produced and consumed in Brazil. Black bean is

Figure 4.2: Production, yield and area sown of common bean, Africa, 1961 to 2014



Source: FAOSTAT data.

1 No separate data are available for the common bean in Africa. Since the major *Vigna* beans grown here are cowpea and bambara bean, which are classified separately in FAOSTAT, for Africa, the FAOSTAT category of dry bean broadly coincides with common bean (*Phaseolus vulgaris*).

Table 4.3: Growth rates of sown area, yield and production of common bean, Brazil, 1961–1985 and 1985–2014 (percent)

	Area	Yield	Production
1961–1985	2.6	–2.0	0.6
1985–2014	–2.0	3.2	1.2

Source: FAOSTAT data.

grown mainly in southern states such as Parana and Rio Grande do Sul, while carioca bean is found in the country's southern, southeastern and northeastern parts.

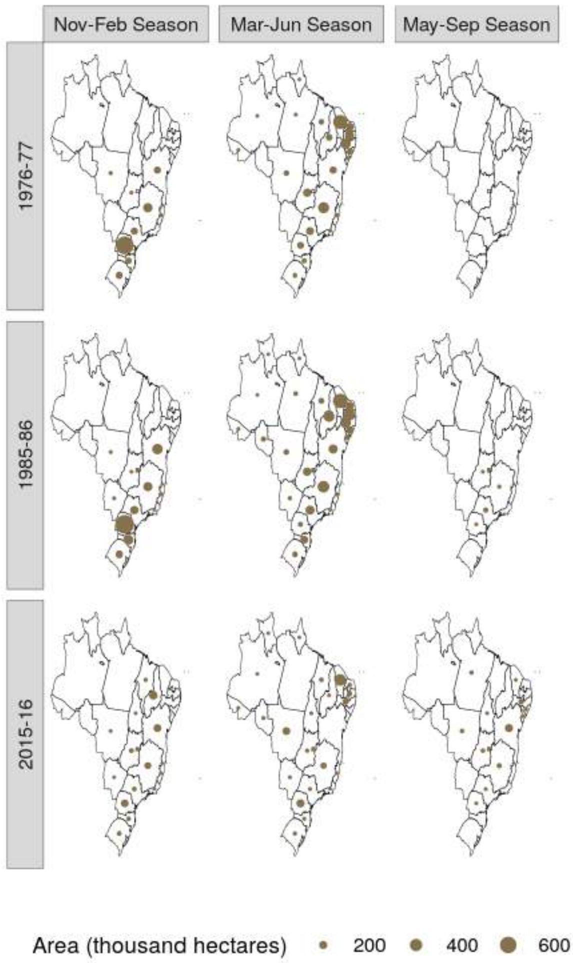
Expansion of the area under common bean and growth in the production of common bean in Brazil occurred in two distinct phases.

1960s to mid-1980s: expansion of area under common bean cultivation

Until the mid-1980s, growth in the production of common bean was primarily on account of expansion of cultivated area. The area sown with beans increased at an annual growth rate of 2.6 percent, from 2.5 million hectares in 1961 to 5.3 million hectares in 1985 (Table 4.3). In the traditional bean-growing areas of Brazil, namely the southern, southeastern and central regions, the rainy season (November to February) was the main cropping season. From the 1960s to the mid-1980s, when cultivation expanded to the Cerrado as well as other parts of northeastern and southeastern Brazil, common bean began to be grown in the dry season (from March to June) (Figure 4.3).

Several initiatives undertaken in the 1970s – including the Programa de Desenvolvimento dos Cerrado (Polocentro, the Programme for Development of Cerrado), Programa Nacional para Aproveitamento de Várzeas Irrigáveis (Pro Várzea, National Programme for Harnessing Irrigable Floodplains), Programa de Financiamento de Equipamento de Irrigação (Profir, Programme for Financing Irrigation Equipment), Programa Nacional de Irrigação (Proni, National Programme for Irrigation) and Programa de Irrigação do Nordeste (Proine, Northeast Irrigation Programme) – and the establishment of the Empresa Brasileira de Pesquisa Agropecuária

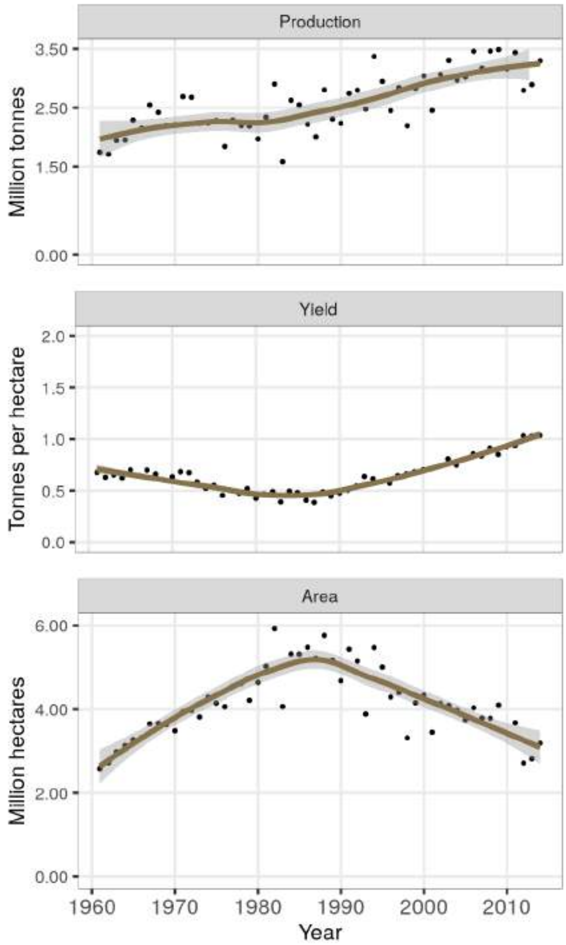
Figure 4.3: Regional and seasonal distribution of area sown with common bean, Brazil, 1976–77, 1985–86 and 2015–16



Source: Data from Companhia Nacional de Abastecimento.

(Embrapa, Brazilian Agricultural Research Corporation) set the basis for the modernization of common bean cultivation. Of these, the Programa de Desenvolvimento dos Cerrado (Polocentro) played a crucial role in expanding cultivation to the Cerrado in the northeast and the Amazon (Rada, 2013). Improving the road infrastructure in Cerrado was also important to facilitate the transportation of both agricultural inputs and agricultural produce. Expansion of cultivation to Cerrado attracted big commercial producers from other regions for large-scale, mechanized farming in the areas newly brought under agriculture (Peloso, Wander and Stone, 2008). Extension of subsidized agricultural credit tied to adoption of modern technology facilitated the expansion and modernization of agriculture (Alves, Contini and

Figure 4.4: Production, yield and area sown of common bean, Brazil, 1961 to 2014



Source: FAOSTAT data.

Gasques, 2008). Empresa Brasileira de Pesquisa Agropecuária (Embrapa) was set up in 1973 to give a push to scientific research in agriculture (Peloso, Wander and Stone, 2008).

It is noteworthy that soil in the Cerrado region was acidic, and despite huge investments in lime treatment and other soil-enrichment measures, the soil fertility in these newly restored regions remained relatively low. As a result of the extension of bean production to these regions, the average yields of common bean declined over this phase at a rate of about 2 percent per annum. The average yield of common bean in 1985–86 was only 405 kilograms per hectare. However, driven by the expansion of area sown, production increased at an annual growth rate of 0.62 percent to reach 2.54 million tonnes by 1985.

Despite the introduction of large-scale farming, production over this period remained dominated by small producers. The extent of use of improved varieties and technology was low. Common bean was mostly intercropped with maize, and sometimes with cassava, coffee and other crops. Farmers used indeterminate cultivars with low planting density. Apart from low soil fertility, frequent droughts, and widespread problems of diseases and pests, low yields were also related to the inability of small peasants to adopt improved and modern technologies (Van Schoonhoven and Voysest, 1989).

Mid-1980s onwards: growth led by increase in yields

The three decades that followed, from the mid-1980s onwards, saw a steep decline – at a rate of 2 percent per annum – in the area sown with common bean (Table 4.3). Between 1986–87 and 2015–16, Brazil saw a shift of about 2.7 million hectares away from production of beans. The decline has been particularly steep in recent years because of the shift towards producing corn for ethanol fuel and large-scale production of soybean for export (Mueller, 2003). Widespread infestation of soil with disease-causing fungi in the major bean-growing states was another reason for the decline.

The decline in area sown with common bean over the last three decades occurred primarily in the months of November to February and March to June – that is, in the rainy and dry seasons. Production in both these seasons is dependent on rains and dominated by small producers. Simultaneously, around the mid-1980s, with the expansion of irrigation, common bean started to be grown in the country's southeastern region in the winter months, from May to September (Figure 4.3). Production in this season is dominated by large-scale industrial farming with greater use of improved technology, chemicals and mechanization. Consequently, yields in this season are much higher than in the other two seasons. In 2015, cultivation in the winter months (May to September) accounted for only about 6 percent of the total area sown with common bean, but contributed about 14 percent of total common bean production (Table 4.4).

Table 4.4: Production, yield and area sown of common bean, by season, Brazil, 2015

Season	Production (million tonnes)	Yield (kilograms per hectare)	Area (million hectares)
First crop (November–February)	1.35	879	1.58
Second crop (March–June)	1.30	1169	1.11
Third crop (May–September)	0.44	2497	0.18
Total	3.09	1079	2.86

Source: Data from Companhia Nacional de Abastecimento.

As a result of the expansion of modernized, irrigated cultivation of common bean in the winter season, overall yields increased significantly, from just 405 kilograms per hectare in 1985 to 1,079 kilograms in 2015. Given the high rate of growth of yields, production increased in this period at a rate of 1.2 percent per annum (Table 4.3).

The increase in common bean yields in Brazil was made possible because of substantial investments in the national agricultural research system (Sistema Nacional de Pesquisa Agropecuária, SNPA), which currently comprises Embrapa, other national and state-level agricultural research institutions, universities, and private research organizations. The Embrapa gene bank has over 14,000 accessions of common bean germ plasm (Peloso, Wander and Stone, 2008). The SNPA has focused on improvements in terms of yield, shorter duration, drought tolerance, improved grain quality, plant height and upright plant structure for mechanical harvesting, and disease resistance (Brito *et al.*, 2015; Brito *et al.*, 2009; Faria *et al.*, 2010; Peloso, Wander and Stone, 2008). Between 1983 and 2006, 121 improved cultivars of common bean were released in Brazil (Peloso, Wander and Stone, 2008). The limited irrigation potential of the Cerrado region necessitated a search for improved drought tolerance and better water-use efficiency in bean production. No-till cultivation was popularized in this region to reduce soil erosion and improve retention of soil moisture (Cremaq, 2010). Erect cultivars suitable for mechanical harvesting were developed to facilitate large-scale sole cropping of common bean. In the early 1990s, Embrapa identified the different agroclimatic zones and the abiotic stresses faced in each zone, as well as provided recommendations regarding appropriate cultivars and agronomic practices for each zone.

Bean golden mosaic virus (BGMV), transmitted by the whitefly, is one of the most devastating disease-causing pathogens for the common bean (Faria *et al.*, 2016). Despite forty years of research, effective resistance for BGMV has not been found within the common bean germplasm. It is estimated that BGMV causes losses to the tune of 90,000–280,000 tonnes per annum. About 200,000 hectares of land in Brazil have become unusable for bean production because of BGMV. Embrapa has recently developed a transgenic event, Embrapa 5.1, which is resistant to the virus; it was approved for commercial release after biosafety assessments in September 2011. Several cultivars have since been developed and put through further field-testing. It is expected that the release of Embrapa 5.1-based varieties will facilitate expansion of common bean production in many areas where it is no longer possible because of BGMV infestation.

Mexico

In 2012–14, Mexico produced 1.2 million tonnes of common bean on 1.6 million hectares of land (Table 4.1). Mexico's production of common bean is primarily driven by domestic demand. According to FAOSTAT data, the average per capita consumption of common bean in Mexico was 9.2 kilograms per annum in the year 2013. Given the shortfall in production to meet the needs of domestic consumption, Mexico also imports substantial quantities of common bean from the US, Argentina and Canada. In 2011–13, Mexico imported 0.16 million tonnes of common bean.

Black bean, pinto bean, pink bean and yellow bean are the main types of common bean produced in Mexico, mainly under rainfed conditions. In 2014–15, out of 1.9 million hectares of land under common bean, 1.6 million hectares were unirrigated. Given the lack of irrigation, bean production is extremely vulnerable to changes in weather conditions.

There are two crop cycles for the cultivation of common bean in Mexico: spring–summer and fall–winter. In Zacatecas and Durango, the two top bean-producing states with an annual production of about 290,000 tonnes and 112,000 tonnes respectively, common bean is cultivated in the spring–summer season under dryland conditions. Of the major bean-producing states, Sinaloa is the only one where common bean is grown on land that is almost entirely irrigated. In Nayarit, almost one-third of bean cultivation takes place under irrigated conditions. In all the other major bean-producing states, less than 15 percent of the cultivated area is irrigated.[2]

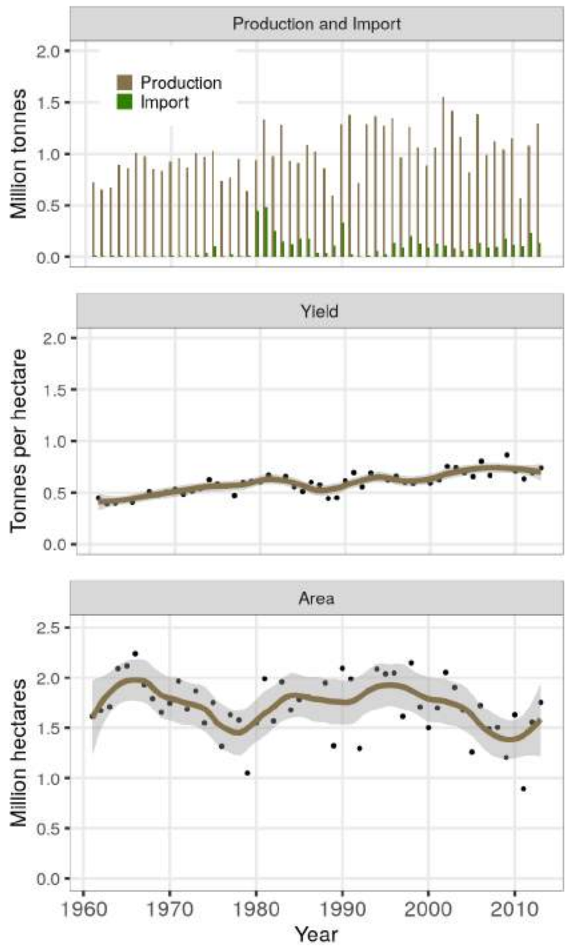
The production of beans in Mexico takes place predominantly on smallholder farms. In 2007, 47 percent of all agricultural holdings in Mexico were less than 2 hectares and 73 percent were less than 5 hectares (UNCTAD, 2013).

Since common bean production in Mexico is characterized by rainfed conditions, small farms with low levels of modernization and adoption of improved technology, the yield levels are very low and exhibit considerable year-to-year variation. In the triennium ending 2014, the average yield of common bean in Mexico was only 738 kilograms per hectare.

Production of common bean in Mexico has been stagnant since the 1990s, when, under the North American Free Trade Agreement (NAFTA), the country opened up to imports from the USA and Canada. Since 1994, Mexico's imports of common bean have been rising by about 3.6 percent per annum. As imports – primarily from the USA – increased, the area under common

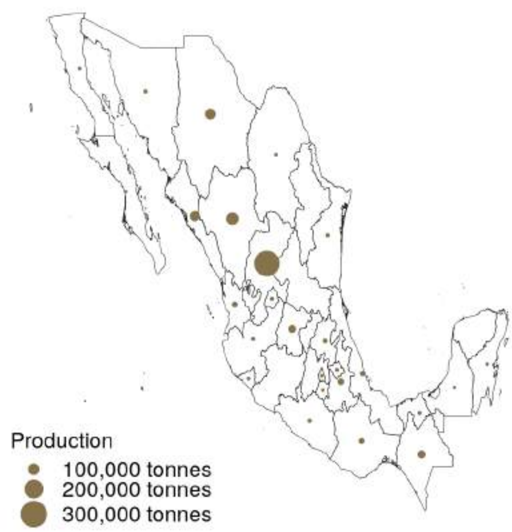
2 Based on data from Servicio de Información Agroalimentaria y Pesquera, Government of Mexico.

Figure 4.5: Production, yield and area sown of common bean, Mexico, 1961 to 2013



Source: FAOSTAT data.

Figure 4.6: State-wise distribution of production of common bean, Mexico, 2015



Source: Data from Servicio de Información Agroalimentaria y Pesquera, Government of Mexico.

bean production fell. Consequent to the decline in area under cultivation and slow rise in yields, domestic production of common bean in Mexico has stagnated at around 1 million tonnes per annum.

Black bean and pinto bean are the major types of common bean imported from the United States. Given that domestic production takes place primarily under rainfed conditions and tends to fluctuate a lot, Mexico has to rely on import of beans from the USA to meet the requirements of domestic consumption in bad crop years. In 2011–12, in the wake of half its common bean crop being destroyed by a devastating famine, Mexico dealt with the crisis by importing 102,000 tonnes of pinto bean, the second most widely consumed bean in the country, from the USA (US Dry Bean Council, 2015).

The United States of America

The United States of America (USA) produces common bean for domestic consumption as well as exports. In the triennium ending 2015, the USA had an annual production of about 1 million tonnes. The production of beans in the USA is characterized by industrialized farming on a very large scale and very high yields. In 2013–15, the average yield of common bean here was 1,987 kilograms per hectare.

Table 4.5: Production, area sown and yield of different types of common bean, USA, 2013–15

	Production (tonnes)	Area (hectares)	Yield (kilograms per hectare)
Pinto bean	422238	225968	1876
Black bean	182573	94685	1944
Navy bean	184977	87724	2118
Great northern bean	72802	30662	2349
Light red kidney bean	48898	22339	2202
Dark red kidney bean	54023	24997	2145
Pink bean	17872	8478	1895

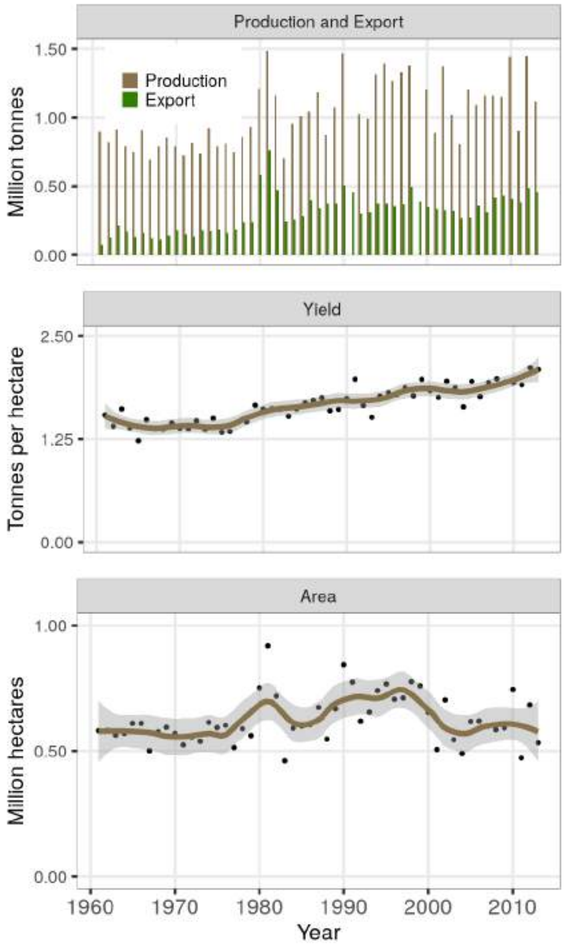
Source: US Department of Commerce data, https://www.statpub.com/index.php/statistics

Table 4.6: Exports of different types of common bean from USA, 2013–15

	Exports	Share of destination (percent)			Top importing countries
	(tonnes)	Europe	Latin America	Other	
Pinto bean	63302	3	80	17	Dominican Republic, Mexico
Black bean	48270	2	90	7	Mexico
Navy bean	152145	43	51	6	UK, Italy
Great northern bean	32530	57	7	35	Turkey, France
Light red kidney bean	9049	10	23	41	France, Netherlands
Dark red kidney bean	42583	72	17	11	UK, Japan
Pink bean	981	0	0	0	Dominican Republic, Mexico

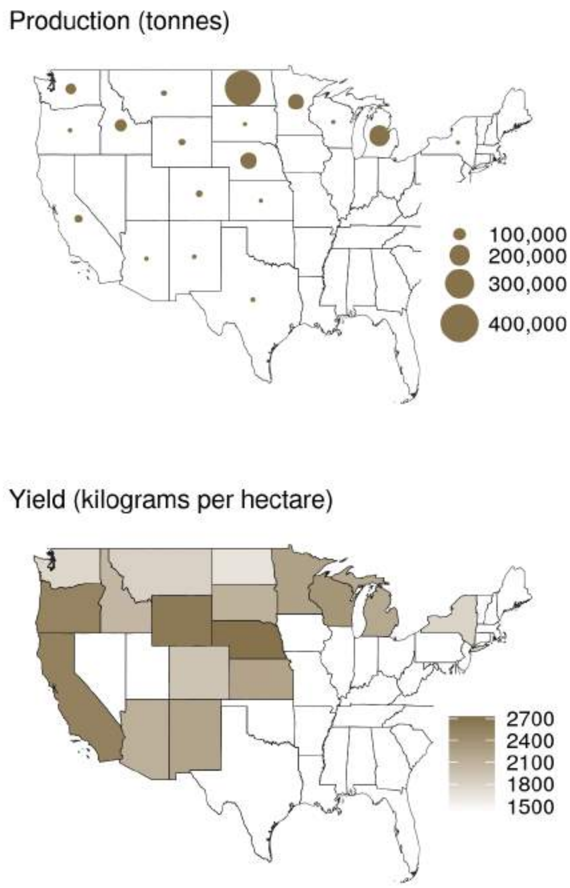
Source: US Department of Commerce data, https://www.statpub.com/

Figure 4.7: Production, yield and area sown of common bean, USA, 1961 to 2013



Source: FAOSTAT data.

Figure 4.8: Production and yield of common bean, by state, USA, 2013–15



Source: US Department of Commerce data, available at https://www.statpub.com/index.php/statistics

The USA produces many varieties of common bean. In 2013–15, of the total production of common bean, 43 percent was pinto bean, 19 percent was black bean and 19 percent was navy bean (Table 4.5). These different types are produced for different markets. Pinto bean is consumed domestically as well as exported. In 2013–15, about 80 percent of exports of pinto bean went to Latin America, with the Dominican Republic and Mexico being the largest importing countries. About 90 percent of exports of black bean went to Latin America and about 65 percent to Mexico. Both Europe and Latin America imported navy bean, with the UK and Italy being the largest importers. Europe was the largest importer of great northern bean and red kidney bean (Table 4.6).

Table 4.6 gives the data on USA exports of different beans. Over 2013–15, the USA exported 0.35 million tonnes of common bean annually. The major items of exports were black bean, navy bean and dark red kidney bean; 40 percent of black bean produced in the USA were exported to Mexico, and 66 percent of navy bean were exported to European nations such as the UK and Italy. The production of dark red kidney bean was primarily driven by export considerations; 90 percent of these beans were exported in 2016. The main countries importing dark red kidney beans were the UK and Japan.

Figure 4.8 shows the levels of production and yield of common bean in different states of the US. North Dakota is the largest bean-producing state. Pinto bean is mainly produced in North Dakota and Nebraska, while production of black bean and navy bean is concentrated in Michigan.

Although North Dakota has the largest area under common bean, the yields here are lower than in other major producing states. In 2015, 0.14 million hectares of land in North Dakota were sown with pinto bean and the per hectare yield was 1,535 kilograms, while 31,000 hectares of land in Nebraska were sown with pinto bean with a yield of 2,723 kilograms per hectare.

Over the last fifteen years, there has been a shift of pulse production in the USA from common bean to dry pea and soybean. In the triennium ending 2001, common bean accounted for 76 percent of the total area under pulses in the US. By 2014, this had fallen to 53 percent. In terms of production, the share of common bean in total pulse production in the USA (which, in USA official statistics, includes soybean) fell from 76 percent in the triennium ending 2001 to 55 percent in the triennium ending 2014. This was because of a shift in production to dry pea, whose share in the area under total pulses rose from 10 percent in 1999–2001 to 26 percent in 2012–14, and also because of an increasing shift to soybean, which has prospects of higher prices and returns (USA Dry Pea and Lentil Council, 2016).

Tanzania

Tanzania is the largest producer of common bean in Africa with annual production of about 1 million tonnes (Table 4.2). Production of bean or *Makanade* in Tanzania is concentrated in the Mbeya and Ruvuma region of the southern highlands; in Manyara, Arusha, Kilimanjaro and Tanga regions of the northern zone; and in Kigoma, Kagera and Lushoto region of the lake zone (Birachi, 2012). Tanzanian farmers cultivate common bean primarily to meet the domestic demand for consumption, and the surplus, if any, is sold in local markets.

Common bean is generally intercropped with maize or banana in the southern highlands and the lake zone of Tanzania, while some monocropping occurs in the northern zone. In 2012, approximately 80 percent of the total common bean cultivated in Tanzania was intercropped with maize and bananas (Birachi, 2012). In 2012–13, the southern highlands accounted for approximately 24.3 percent of the total area under common bean in Tanzania (Letaa *et al.*, 2014), and common bean accounted for 38 percent of the total cropped area of the southern highlands in 2012. Production in the southern highlands and the lake region of Tanzania is dominated by small, resource-poor farmers who grow beans for subsistence. The northern zone, characterized by better endowment of resources such as tractors and animals, has some commercial production of common bean.

The production of common bean in Tanzania has seen a steady rise over the last five decades, at an average annual growth rate of about 4.4 percent. While this has been primarily driven by a steady expansion of the area sown with common bean (at an annual rate of about 3.1 percent), yields too have shown a steady increase (Figure 4.9). The Tanzanian government implemented the National Bean Research Programme (NBRP) with the support of the International Centre for Tropical Agriculture (CIAT) and the Eastern and Central Africa Bean Research Network (ECABREN); under this programme, several improved varieties of common bean, including Lyamungu 85, Lyamungu 90, Selian 94, Selian 97 and Jesca, have been released in Tanzania (Xavery *et al.,* 2006). Due to a strong push through public extension services, there has been a significant increase in the adoption of improved varieties of bean in Tanzania since the 1980s. A sample survey conducted by the NBRP in 2004 in six districts of the country found that 76 percent of the farmers used improved varieties (Xavery *et al.*, 2006), and that Lyamungu 85 and Lyamungu 90 were popular varieties among the farmers. The Pan African Bean Research Alliance (PABRA) released many varieties of common bean in the southern highlands between 2002 and 2010 that had an average yield gain of 437 kilograms per hectare over the local varieties. In the following two years, these varieties were adopted by about 23 percent of farmers of this region (see Box 4.2). It was estimated that in 2012, 65 percent of the area under common bean in the southern highlands of Tanzania was sown with improved varieties. The total value of productivity increase due to the adoption of these improved varieties was estimated at USD 12.5 million per annum (International Center for Tropical Agriculture, 2014).

Uganda

Uganda is the second largest producer of beans in Africa. In 2012–14, it produced 0.9 million tonnes of common bean on 0.67 million hectares of land (Table 4.2). The area sown with common bean in Uganda has seen a steady rise from 1980 to 2010. There has, however, been a significant decline in yields since the 1990s. While the average yield in Uganda was close to 800 kilograms per hectare in the early 1990s, by 2010 this had fallen to less than 500 kilograms per hectare. Although the increase in area under common bean resulted in an increase in production over the 1990s, overall production declined in the 2000s (Figure 4.9).

Beans are cultivated in Uganda in the long rainy season of September to November, as well as in March to June. According to the last Agricultural Census report, about 59 percent of the production in 2008–09 was in September–November (Uganda Bureau of Statistics, 2010). A survey of seventeen bean-producing districts of Uganda conducted by Kilimo Trust (2012) found that production is primarily small-scale with the average size of landholdings per household being 0.4 hectare. While sowing of local varieties is common, the survey reported that K132, a bush-type, disease-resistant variety, is the most widely adopted improved variety in Uganda. It was found, however, that even on farms where improved varieties have been adopted, considerable gaps remain between actual and potential yields.

Common bean is produced in Uganda mainly for domestic consumption. Although there has been a decline in per capita consumption with a growth in population, overall demand has continued to rise (Kilimo Trust, 2012). Exports accounted for only 4 percent of common bean produced in 2011–13 (Table 4.7). It is, however, likely that there is some underestimation of exports from Uganda on account of informal border trade with South Sudan and Kenya. Informal trade usually happens in small quantities since the transporters are individuals on foot or on bicycles (Mauyo *et al.*, 2010). It has been noted that due to the stringent procedures, phytosanitary requirements and economic costs of formal trade, a considerable amount of the trade with Kenya takes place informally (*ibid.*). Estimates from the Agribusiness Development Centre reported by Mauyo *et al.* (2007) show that between 1990 and 1998, annual average informal exports of common bean accounted for 84 percent of total exports. Another estimate reported by the same source for 2000 suggests that 44 percent of the total quantity was informally traded. Quarterly reports of the Food Security and Nutrition Working Group of FEWS NET have been monitoring and reporting on informal border trade since 2012. In 2011–12 it was estimated that 150,000 tonnes of common bean were informally exported by Uganda (Food Security and Nutrition Working Group, 2012).

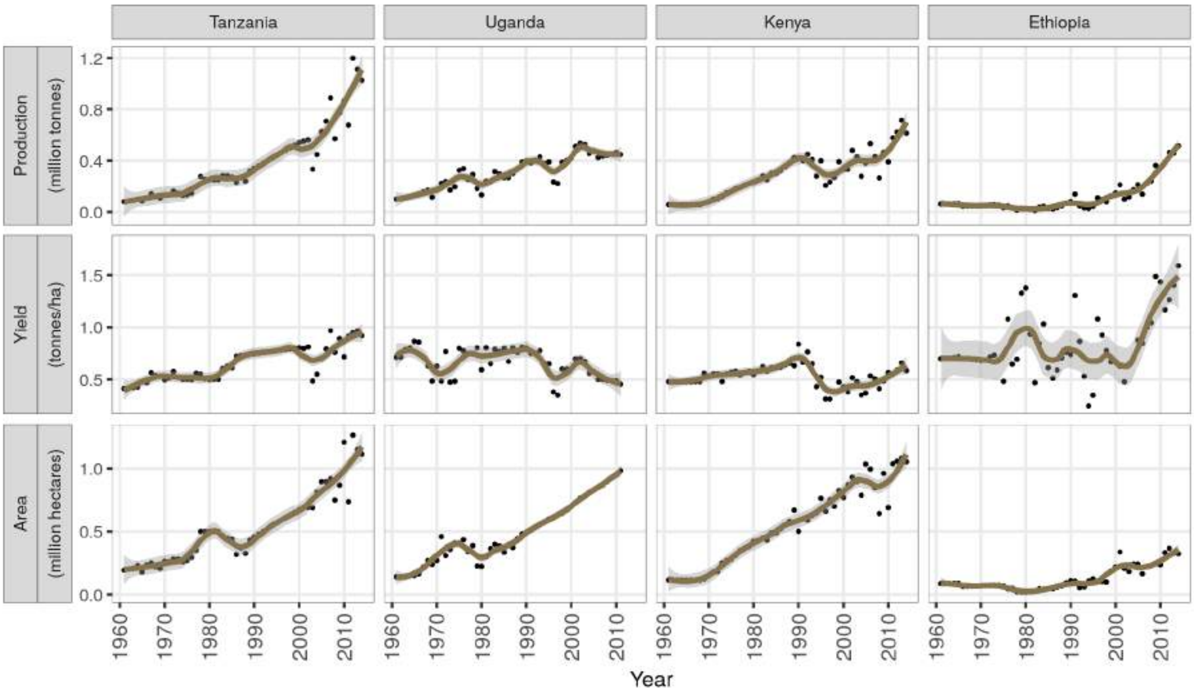
Kenya

Common bean is the most important pulse crop of Kenya and it accounted for 64 percent of the country's total pulse production in the triennium ending 2014. Despite this, yields of common bean in Kenya are very low and have been stagnating (Figure 4.9). In 2012–14, the average per hectare yield of common bean was only 611 kilograms (Table 4.2). Between 1970 and 2002, there was a rapid increase in the production of common bean in Kenya because of expansion in the area sown with beans at a rate of 4.6 percent per annum.

Bean production in Kenya is concentrated in the counties of the eastern and central region (Figure 4.10). The Rift valley accounted for 33 percent and the western region for 22 percent of total bean production in 2005. In both these regions bean is cultivated in the months of March to May, whereas in the eastern region bean is cultivated in March to May as well as in October to December (Katungi *et al.*, 2009). Bungoma, Meru and Machakos counties recorded the highest levels of production in the country, more than 50,000 tonnes each, in 2013. In terms of per hectare yield, Nairobi, Busia and Isiolo, with yields above 1,300 kilograms per hectare, rank at the top (Central Planning and Project Monitoring Unit, 2015).

Common bean production in Kenya is driven by domestic demand. Kenya also imports a large quantity of beans from Uganda, Tanzania and Ethiopia via informal trade (Katungi *et al.*, 2009).

Figure 4.9: Production, yield and area harvested of common bean in major producing countries of Africa, 1961 to 2014



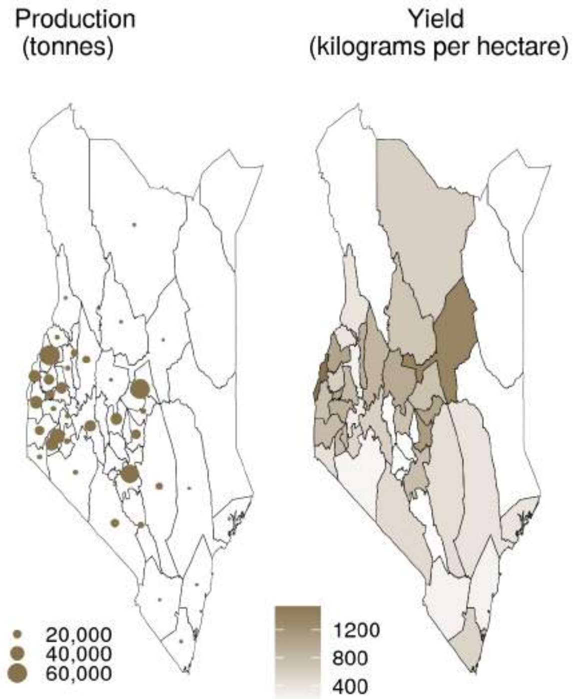
Source: FAOSTAT data.

Box 4.2: Breeding of varieties of common bean in Africa

Improved varieties of common bean have been developed in Africa with the objective of promoting commercial cultivation. The International Center for Tropical Agriculture (CIAT) has led the research on common bean in Africa since the mid-1980s. In collaboration with national research organizations, CIAT has produced 450 high-yielding and disease-resistant varieties. In 1996, CIAT established the Pan African Bean Research Alliance (PABRA) to accelerate decentralized research on common bean. PABRA operates in twenty-nine countries across three networks: the Southern African Bean Research Network (SABRN), Eastern and Central Africa Bean Research Network (ECABREN), and West and Central Africa Bean Research Network (WECABREN). PABRA initiated the development of various stress-resistant varieties, and produced 156 such varieties between 2009 and 2014. A baseline study was conducted by PABRA to see the adoption and effect of improved varieties in Ethiopia and the southern highlands of Tanzania. In Ethiopia, 48 new varieties of common bean were released between 2003 and 2012. A sample study showed that of these, 17 varieties were adopted by 36 percent of the households under study. On average, improved varieties gave an average yield gain of 187 kilograms per hectare (International Center for Tropical Agriculture, 2014).

Between 2007 and 2014, support under the Tropical Legume-II (TL-II) project helped accelerate the breeding work of PABRA and CIAT. Through TL-II, nurseries were established in many African countries, including Malawi, Zimbabwe, Kenya, Uganda and Tanzania, for breeding improved seed varieties. From 2007 to 2014, 73 new varieties with desirable traits like drought tolerance, disease resistance and low cooking time were released in the six TL-II countries (Malawi, Ethiopia, Kenya, Uganda, Zimbabwe, and northern zone and southern highlands of Tanzania). Between 2008 and 2013, 42,238 tonnes of breeder seed were produced in the participating countries, with the highest seed production (23,616 tonnes) recorded in Ethiopia. Under TL-II, training was imparted through farmer support groups. Between 2008 and 2014, about 60,000 tonnes of improved seeds of common bean were sold to farmers in small packets (Monyo and Varshney, 2007).

Figure 4.10: Production and yield of common bean, by county, Kenya, 2013



Source: Data from Central Planning and Project Monitoring Unit (2015).

Ethiopia

Of all the common bean-producing countries in Africa, Ethiopia is the largest exporter, accounting for 41 percent of common bean exports from Africa (Table 4.7). Production of common bean in Ethiopia has seen a steadily rising trend over the last two decades (Figure 4.9). The rise in production – at 10.5 percent per annum – has been particularly high due to a very high increase of yield (5 percent per annum) as well as a large expansion in the area annually sown with common bean (a growth rate of 5.5 percent per annum). After faba bean, common bean is the most important pulse crop of Ethiopia. In 2012–14 Ethiopia produced 0.48 million tonnes of common bean, which accounted for 17.7 percent of total production of pulses and of which about 37 percent was exported.

Ethiopia exports common bean to several European countries, the Middle East and the Far East. Exports of common bean from Ethiopia steadily increased between 2000 and 2013, at a rate of 16.2 percent per annum (Figure 4.12). In 2011–13, 0.16 million tonnes of beans, accounting for 37 percent of total production, were exported from Ethiopia.

Production of common bean takes place in rainfed conditions in Ethiopia, on small plots ranging from 0.3 to 5 hectares in most regions. On smallholder farms common bean is often intercropped with sorghum and maize, and is mainly produced in the *Meher* (June to October) season (Ferris *et al.*, 2012).

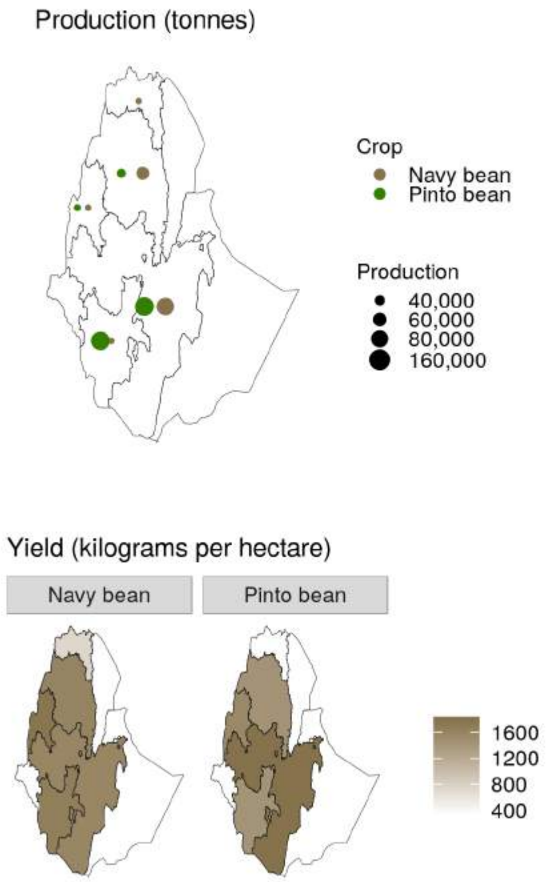
Oromia region in Ethiopia is the largest producer of bean (Figure 4.11 and Wortmann *et al.*, 1998). It produces navy bean for exports and pinto bean mainly for domestic consumption. A substantial quantity of navy bean is also produced in Amhara region. Ethiopia exports navy bean mainly to the European countries, with the United Kingdom (UK) being the largest importer (Ferris *et al.*, 2012). More than 50 percent of beans produced in the Oromia region are exported (Monyo and Varshney, 2007). Varieties such as Michigan pea bean and Mexican 142 are

Table 4.7: Annual exports, ratio of exports to production and share in exports from Africa, major common bean-exporting countries, Africa, 2011–13

Country	Exports quantity (thousand tonnes)	Ratio of exports to production (percent)	Share in exports from Africa (percent)
Ethiopia	160	37	41
Egypt	62	72	16
Uganda	27	4	7
Madagascar	23	22	6
Africa	1155	7	100

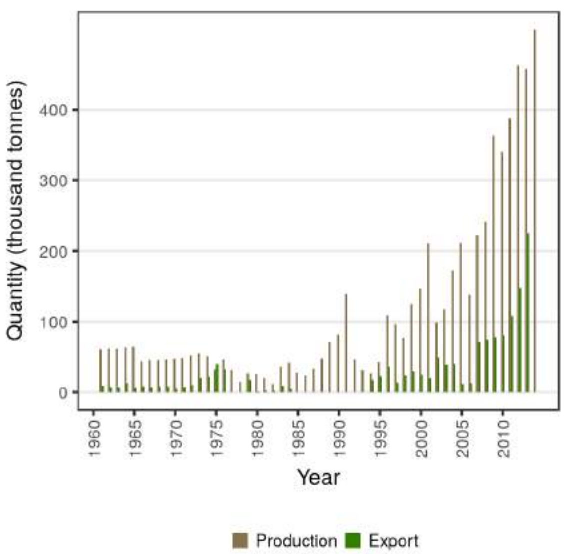
Source: FAOSTAT data.

Figure 4.11: Production and yield of common bean, by county, Ethiopia, 2013



Source: Data from Central Statistical Agency, Ethiopia.

Figure 4.12: Production and exports of common bean, Ethiopia, 1961 to 2013



Source: FAOSTAT data.

popular navy bean varieties, primarily produced for export. The SNAP region, also a major bean-producing area, mainly produces pinto bean (Figure 4.11).

The Tropical Legume-II (TL-II) project has played an important role in increased adoption of improved varieties of bean. Of all the African countries covered by this project, Ethiopia has shown the largest adoption of improved varieties. In 2011, 90 percent of the area under common bean in the country was sown with improved varieties.

Cost of production and margins

Data on cost of production and margins in common bean cultivation suggest that average margins are higher in countries with modern, large-scale production than in countries with low yields. Tables 4.8 to 4.10 present data on cost of production and gross margins (gross revenues minus variable costs) relating to the cultivation of common bean in North Dakota (the United States), commercial farms in Brazil, Valle del Fuerte (Mexico), Kenya and Uganda. It must be pointed out that for both North Dakota and Brazil, production cost figures are for modern farms. While yield estimates used in the data for North Dakota are close to average yields for the US, this is not the case with regard to the data for Brazil. Production of common bean in Brazil takes place on small peasant holdings, often as part of complex cropping systems, as well as on large-scale commercial farms with monocropping. The data presented here reflect estimates for large-scale commercial farms, which have yields much higher than the average yields for all of Brazil. Having noted this caveat, one can see that there are huge variations in the structure of costs, output and gross margins across different countries.

First, these data show that the returns are highest for commercial farms in Brazil with a summer crop of common bean (729 to 1,376 kilograms per hectare), followed by North Dakota farms (642 to 774 kilograms per hectare). Uganda and Kenya are characterized by low-cost production with low yields and low gross margins. On the other hand, cost of production of

Table 4.8: Gross value of output, costs and gross margin for common bean farming in North Dakota, United States, 2015 (equivalent kilograms of common bean)

Output, costs and gross margin	Southeast	South Red River Valley	South Central	East Central
Output				
Gross value of output (USD per hectare)	400	430	363	390
Yield (kilograms per hectare)	1600	1720	1450	1560
Producer price (USD per kilogram)	0.25	0.25	0.25	0.25
Variable costs				
Seed	176	176	176	176
Fertilizer	176	184	145	180
Plant protection chemicals	263	246	183	263
Machinery	166	175	152	165
Crop insurance	52	83	80	64
Miscellaneous	51	62	51	51
Interest on working capital	19	20	17	19
Total variable costs	904	946	804	918
Gross margin at farm gate				
Gross margin	696	774	646	642
Gross margin (USD per hectare)	174	193	161	160

Source: Crop Budgets, North Dakota State University, https://www.ag.ndsu.edu/farmmanagementbudget-archive

bean is very high in Valle del Fuerte, Mexico, and despite a yield of about 1.8 tonnes per hectare, the gross margins are very low.

In North Dakota in the US, the average yield of bean varies from 1,450 to 1,720 kilograms per hectare. The cost, in equivalent kilograms of bean, is highest for plant protection (22–29 percent), followed by fertilizer (18–20 percent), seeds (18–19 percent) and machinery (18–19 percent). Overall variable costs, in equivalent kilograms of bean, vary between 804 to 946 kilograms of bean.

In Brazil, cost of production is much higher in the dry season in São Paulo, primarily on account of greater expenditure on fuel and labour, than in the rainy season in the three states for which data are available. Despite high yields of the dry season crop, the returns are lower (equivalent to 431 kilograms of common bean) than for the rainy season crop.

In contrast, data from Kenya and Uganda present cases of low-yield production of common bean on smallholder farms in Africa. With very low levels of modern inputs and use of local seed varieties, farm yields are below 1 tonne per hectare. In the absence of use of modern inputs, land preparation and labour for harvesting are the two major items of expenditure. This results in very low gross margins – equivalent to only about 3 quintals of common bean per hectare.

Mung and Urd Beans

Mung bean (green gram, *Vigna radiata*) and urd bean (black gram, *Vigna mungo*) are the most widely grown pulse crops of the *Vigna* species. They are prominent in Asia, especially in India, Myanmar, Bangladesh, China, Pakistan, Thailand and Sri Lanka. These are warm season grain legumes which grow in tropical regions and require warm temperatures for germination

Table 4.9: Gross value of output, costs and gross margin for common bean farming in Brazil, 2015 (equivalent kilograms of common bean)

Output, costs and gross margin	Rainy season			Dry season
	Goiás	Minas Gerais	Paraná	São Paulo
Output				
Gross value of output (USD per hectare)	1540	1797	1059	1383
Yield (kilograms per hectare)	2400	2700	1750	2700
Price (USD per kilogram)	0.64	0.67	0.61	0.51
Variable costs				
Seed	127	149	112	178
Fertilizers and manure	402	509	291	461
Plant protection chemicals and inoculants	420	527	250	557
Labour	54	19	239	455
Machinery	105	118	129	619
Total variable costs	1108	1324	1021	2269
Gross margin at farm gate				
Gross margin	1292	1376	729	431
Gross margin (USD per hectare)	829	916	442	220

Source: CONAB.

(Panwar and Srivastava, 2012). The proteins of these beans are highly digestible. Mung bean and urd bean native to the Indo-Burmese region are of various cultivated and wild varieties, differing in seed size, colour and other traits.

Mung and urd beans are short-duration crops with a maturity period of just 60 to 90 days. They are often intercropped with maize, sorghum, cotton, millets and pigeonpea because of their short maturity period, or are rotated with cereal crops. Intercropping mung and urd beans with other crops results in improved soil fertility, low incidence of pests and diseases, and higher production of dry matter (Yadav, Kushwaha and Sushant, 2006).

Constraints on yield

The quality, size and grain yield of mung and urd beans are sensitive to various biotic and abiotic stresses. The major biotic stresses include viral and fungal diseases (see Box 4.3). Nematodes such as root-knot nematode (*Meloidogyne incognita* and *M. javanica*), cyst nematode (*Heteroderacajani*) and reniform nematode (*Rotylenchulusreniformis*) are the major pests of mung and urd. Substantial yield losses occur due to cultivation of mung and urd beans on nematode-infested fields (Singh, Dixit and Katiyar, 2010). Mung and urd do not compete well with weeds, and if there is too much soil moisture, weeds can pose a major problem in their cultivation. While crop rotation and use of short-duration varieties to avoid rain and intercropping help prevent the growth of weeds, given the low levels of herbicide resistance, manual weeding is the only way to remove weeds (Varshney and Singh, 2006).

Waterlogging and salinity are the major abiotic stresses in the cultivation of mung and urd beans. Premature sprouting of mung bean due to rainfall during the reproductive stage can also cause considerable yield damage (Sharma and Dhanda, 2014).

Table 4.10: Gross value of output, costs and gross margin for common bean farming in Mexico (Valle del Fuerte, 2015–16), Kenya (2010–13) and Uganda (2012) (equivalent kilograms of common bean)

Output, costs and gross margin	Mexico (Valle del Fuerte, 2015–16)	Kenya (2010–13)	Uganda (2012)
Output			
Gross value of output (USD per hectare)	1477	663	474
Yield (kilograms per hectare)	1800	700	990
Producer price (USD per kilogram)	0.82	0.95	0.48
Variable costs			
Seed	215	38	72
Fertilizers and manure	203	96	
Plant protection chemicals and inoculants	61	29	
Labour	98	115	172
Machinery (land preparation)	224	44	356
Harvesting, sorting and packaging	225	55	83
Miscellaneous	397	4	
Total variable costs	1423	380	683
Gross margin at farm gate			
Gross margin	377	320	307
Gross margin (USD per hectare)	309	303	147

Source: http://www.aarfs.com.mx/imagenes/COSTO_PRODUCCION_FRIJOL_2015–16.pdf; Fintrac Inc. (2013); Kilimo Trust (2012).

Mung and urd beans production in India

India is the largest producer and consumer of mung and urd beans. In 2011–13, these beans accounted for about 26 percent of the total area under pulses in the country. In the same years, India had an average annual production of 1.48 million tonnes of mung bean and 1.8 million tonnes of urd bean.

Yields of mung and urd beans in India are extremely low, and have seen only a small increase in recent years. In 2011–13, the average yield of mung bean was 469 kilograms per hectare and that for urd bean 569 kilograms per hectare. Over the last two decades, the area under the two crops has seen a decline (Tables 4.11 and 4.12).

Cultivation of urd and mung beans is spread across large parts of the country (Figure 4.13). They are grown in northern, central and western India primarily in the summer months (March–June) and in the *kharif* season (June–September), and in the southeastern parts of India in the *rabi* season (November–April) . *Kharif* season mung and urd account for about 70 percent of the total production of these crops. It is, however, noteworthy that *rabi* season cultivation of urd and mung has expanded because of the adoption of improved short-duration (65–80 days) varieties. With the adoption of improved varieties, and because of lower biotic and abiotic stresses in areas where *rabi* season cultivation takes place, *rabi* crops have seen higher per hectare yields (689 kilograms per hectare for urd and 556

Table 4.11: Average production, yield and area sown of mung bean, India

Triennium ending	Production (million tonnes)	Yield (kilograms per hectare)	Area (thousand hectares)
1971	0.63	322	1955
1981	0.91	327	2760
1991	1.33	391	3403
2001	1.07	357	3003
2013	1.48	469	3187

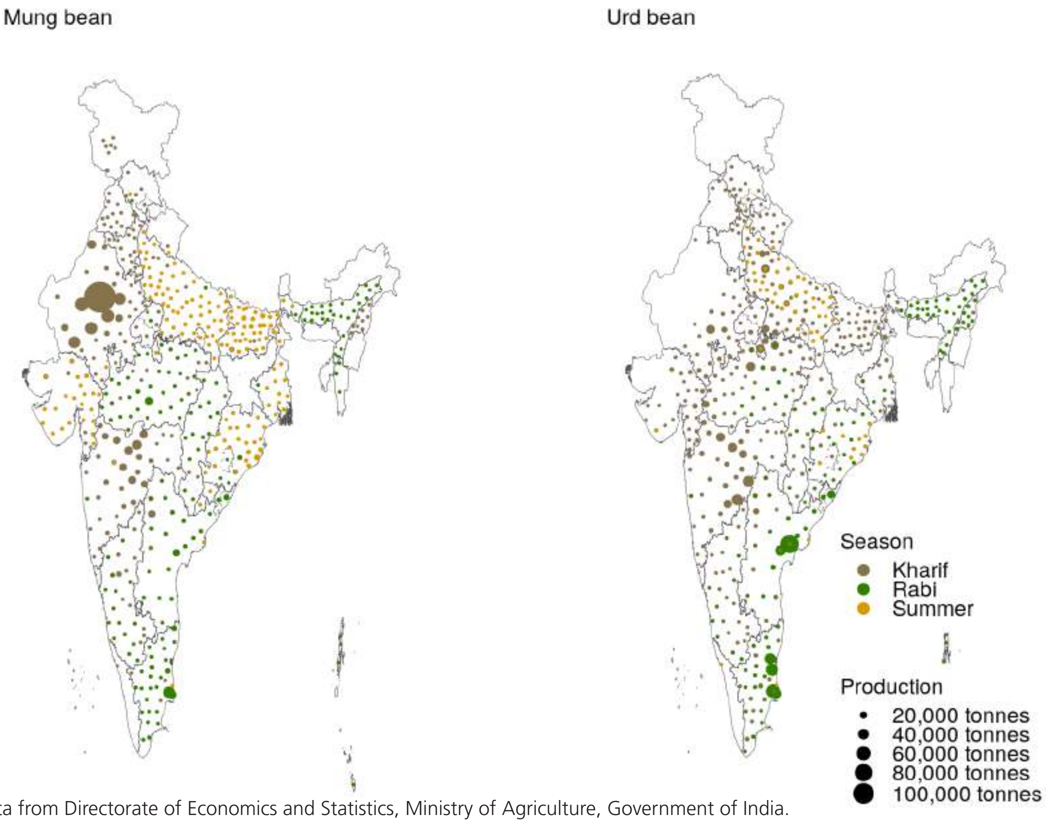
Source: Data from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

Table 4.12: Average production, yield and area sown of urd bean, India

Triennium ending	Production (million tonnes)	Yield (kilograms per hectare)	Area (thousand hectares)
1971	0.60	302	1970
1981	0.91	327	2773
1991	1.59	466	3407
2001	1.38	446	3083
2013	1.79	569	3183

Source: Data from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

Figure 4.13: Production of mung and urd beans in India, 2012–13



Source: Data from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

Box 4.3: Major diseases and pests of mung and urd beans

Mung bean yellow mosaic virus (MYMV) is a major viral disease that causes immense damage to both mung and urd beans in Asia. This disease is transmitted by the white fly (*Bemisiatabaci Gen*). It results in puckering of leaves and a reduction in their size (Sahni, Prasad and Kumari, 2016). Moth bean is also highly susceptible to MYMV (Panwar and Srivastava, 2012). Various bean varieties that are resistant to MYMV have been developed.

Powdery mildew is a fungal disease common in areas with rice-based cropping systems. This occurs in the winter/dry season and is thus more prone to be found in countries where urd and mung bean production takes place in winters. In India, it mainly affects the winter crop grown in the peninsular region.

Ceracospora leaf spot is a more severe disease in mung bean than in urd bean. It causes leaf-spotting and defoliation.

Although varieties with resistance to MYMV and powdery mildew have been developed, pests like *Helicoverpa*, white fly, bean aphid, leaf hopper, green and brown mirids, bean pod borer and thrips continue to cause substantial damage.

A number of mung bean introgression lines have been developed and released under the All India Coordinated Pulses Improvement Project. An important breeding strategy for mung bean has been to cross mung and urd beans with mung as the female parent. This has resulted in transfer of the two most desirable traits – durable resistance against MYMV and synchronous pod maturity – from urd to mung. Synchronous pod maturity is essential in countries where the picking of mung bean is not mechanized and involves high labour costs. These lines have the additional benefit of an improved amino-acid profile (Singh, Gupta and Mishra, 2006). A few such lines for mung bean are: HUM 1 (developed for the *kharif* season), HUM 16 (a shorter-duration variety) and IPM 99–125 (Meha, developed for the spring season). For urd bean, VBG 04–008, a popular variety, was released in 2011.

Source: Project Coordinator's Report (Mung bean and Urd bean): 2015–2016, 2016.

kilograms per hectare for mung in 2011–13) than *kharif* crops (540 kilograms per hectare for urd and 428 kilograms per hectare for mung).

Given the slow rate of growth of production, India has become increasingly dependent on imports for its requirement of mung and urd beans. In 2012–13, the country imported 0.64 million tonnes of urd bean and 0.54 million tonnes of mung bean (Kshirsagar, 2014; www.statpub.com). Myanmar, Tanzania, Australia, Mozambique and Uzbekistan are India's main trading partners for these pulses.

Research on breeding of mung and urd beans in India is supported by the All India Coordinated Research Project on MULLaRP[3] of the Indian Council of Agricultural Research (ICAR). Developing varieties with a maturity period of just 55–60 days has been a major priority for mung and urd breeders in recent years. Release of such varieties has made it possible to grow mung and urd beans as irrigated pre-*kharif* crops between the *rabi* harvest and *kharif* sowing seasons in the Indo-Gangetic plains (Figure 4.13). There is, however, a large untapped potential for expanding the cultivation of these short-duration varieties of mung and urd beans in the Indo-Gangetic plains. With low average yields, there is also considerable scope for increasing productivity by using improved seeds and better agronomic practices. These changes require expansion of irrigation, provision of improved seeds and extension activities among farmers (Singh, Gupta and Mishra, 2006).

Mung bean production in China

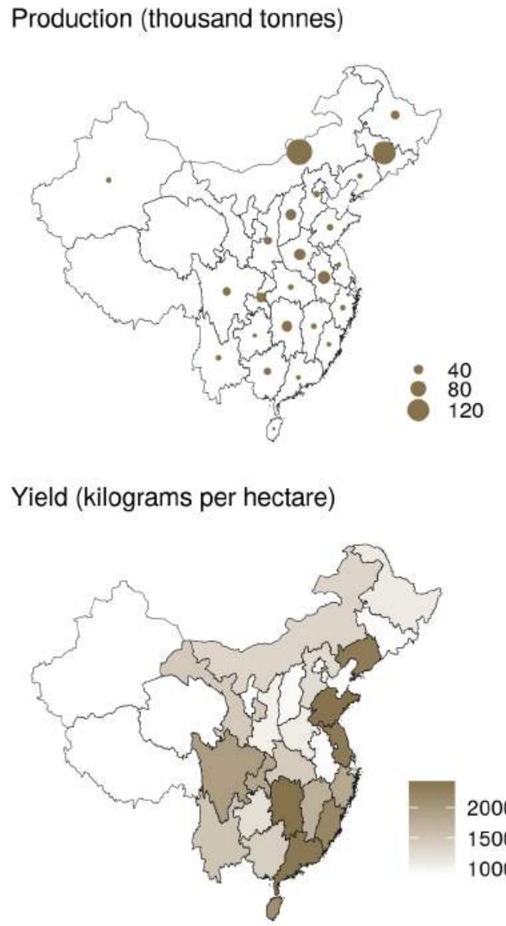
China produces mung bean mainly for domestic consumption. In 2014–15, China's mung bean production, concentrated in Inner Mongolia, Jilin, Anhui and Henan provinces, was estimated to be 0.6 million tonnes, but there has been a decline in the area under mung in recent years (GAIN, 2014). Mung bean is consumed in China as sprouts and is used in the production of noodles; new varieties have been developed for good sprouting.

3 MULLaRP refers to mung bean, urd bean, lentil, lathyrus, rajma and pea.

China led the world in mung bean yields with an average yield of 1,276 kilograms per hectare in 2014. In the lower and middle Yangtze river valley, mung bean is sown in early June and harvested in middle–late August. The field is doublecropped, with mung bean cultivation followed by cultivation of wheat, maize, cotton, sweet potato or canola. On monocropped lands in northern China, mung bean is sown in April–May and harvested in early September as part of the crop rotation comprising mung bean, sorghum and maize. In these areas, mung bean is also intercropped with millets, sorghum and maize. In doublecropped lands in northern China, mung bean is intercropped with summer wheat (Li *et al.*, 2016).

Considerable research has gone into developing varieties of mung bean that are high-yielding and disease-resistant, that sprout well and have high protein content (Cheng and Tian, 2011; Huijie *et al.*, 2003). Research on legumes in China is led by the Institute of Crop Germplasm Resources of the Chinese Academy of Agriculture Sciences. National gene banks have a collection of over 5,000 accessions of mung bean. Pedigree selection, cross-breeding, radiation breeding and marker-assisted breeding have been used to develop many improved varieties of mung bean (Cheng and Tian, 2011). Huijie *et al.* (2003) estimated that the net value of benefits of mung bean research in China was at least USD 53 million.

Figure 4.14: State-wise distribution of production of mung bean, China, 2012–13



Source: National Bureau of Statistics of China.

Export-oriented production in Myanmar

Myanmar has emerged as an important producer and exporter of urd bean (locally called black matpe bean) and mung bean since the late 1980s. Myanmar produces mung and urd primarily for exports, and is the largest exporter of these beans in the ASEAN (Association of South East Asian Nations) region. China is the biggest importer of these beans from Myanmar. Mung bean is also exported by Myanmar to Vietnam and Singapore.

In 2013–14, mung bean was grown on 1.26 million hectares of land and urd bean on 1.1 million hectares in Myanmar. In this period, mung accounted for 28 percent of pulse production in Myanmar and urd for another 24 percent. Urd bean is mainly grown in the lower Myanmar regions: in Bago (44 percent) and Ayeyarwaddy (41 percent). Mung bean has recently seen a rise in production in the upper Myanmar regions: in Magway (24 percent) and Sagaing (16 percent) (Dasgupta and Roy, 2015; Fujita and Okamoto, 2006).

Table 4.13 shows that production of urd bean in Myanmar rose from 1.34 million tonnes in 2007–08 to 1.58 million tonnes in 2014–15, and of mung bean from 1.16 million tonnes in 2007–08 to 1.51 million tonnes in 2014–15. This growth was made possible because of the adoption of improved varieties that enabled cultivation of pulses after harvesting of rice, using the residual soil moisture. Cultivation of urd and mung in Myanmar is almost entirely rainfed. According to Zorya *et al.* (2016), levels of mechanization are low, and labour costs account

Table 4.13: Production of mung and urd beans, Myanmar (million tonnes)

Year	Mung bean	Urd bean
2007–08	1.16	1.34
2008–09	1.21	1.41
2009–10	1.30	1.47
2010–11	1.37	1.56
2011–12	1.31	1.34
2012–13	1.38	1.55
2013–14	1.45	1.57
2014–15	1.51	1.58

Source: Data from Ministry of Agriculture, Myanmar.

Table 4.14: Exports of mung and urd beans, Myanmar (million tonnes)

Year	Mung bean	Urd bean
2007–08	0.33	0.51
2008–09	0.32	0.35
2009–10	0.30	0.62
2010–11	0.27	0.46
2011–12	0.35	0.60
2012–13	0.30	0.66
2013–14	0.33	0.63
2014–15	0.33	0.51

Source: Data from Ministry of Agriculture, Myanmar.

for a large share of the total cost of production for both types of bean.

Other producers of mung and urd beans

Other countries in Asia and Oceania that are large producers of mung and urd beans include Bangladesh, Pakistan, Australia and Cambodia. Table 4.15 gives the production figures in these countries for the latest years for which data are available.

Pakistan's mung bean production rose from 69,000 tonnes in 1993–94 to 178,000 tonnes in 2007–08, primarily on account of expansion of cultivated area. There has, however, been a sharp decline in production over the last decade, and, consequently, Pakistan has emerged as a large importer of mung and urd beans. In 2014–15, Pakistan produced only 99,000 tonnes of mung bean and 9,000 tonnes of urd bean (Table 4.15).

In recent years, export-oriented production of mung bean has started in Australia. In 2011–12, 84,000 tonnes of mung bean were exported from Australia. Over 95 percent of Australian mung bean is exported to the Asian countries, with India being the largest buyer (Gleeson *et al.*, 2014). Mung bean production in Australia is concentrated in Queensland and New South Wales. Of all the countries producing mung bean, Australia stands out as one where the production is fully mechanized. The Australian National Mung Bean Improvement Programme has focused on releasing varieties like Crystal, Satin-

Table 4.15: Area sown and production of mung and urd beans, selected countries

Country	Year	Mung bean		Urd bean	
		Production (thousand tonnes)	Area (thousand hectares)	Production (thousand tonnes)	Area (thousand hectares)
Pakistan	2014–15	98.9	127.5	9.0	20.8
Bangladesh	2014–15	32.7	38.8	31.0	38.9
Cambodia	2012	74.6	62.7		

Source: Data from Ministry of National Food Security and Research, Government of Pakistan; Bangladesh Bureau of Statistics; Dasgupta and Roy (2015).

II and Jade-AU, which are high-yielding and can be mechanically harvested (Agtrans Research, 2011).

Costs of production and returns from cultivation of mung and urd beans

Data on cost of production and returns from mung bean cultivation are available for India, Myanmar and Australia. The data for Myanmar are from a survey of four states which primarily covered villages that were close to towns, had better infrastructure, and better access to public services and markets than remote villages. Given the criteria for selection of villages, the average yields and average returns reported by the survey were probably higher than the averages for Myanmar as a whole. To facilitate comparability across countries, estimates of variable costs and gross margins presented in Tables 4.16 and 4.17 were converted to equivalents of mung and urd beans using producer prices.

Mung and urd beans production in India has very low yields, low costs and very low margins. This explains the stagnation of production of

Table 4.16: Gross value of output, costs and gross margin for mung bean, India, Myanmar and Australia (equivalent kilograms of mung bean)

Output, costs and gross margin	India* (2013–14)	Myanmar (2013–14)	Australia (2012–13)
Output			
Gross value of output (USD per hectare)	376	795	1199
Yield (kilograms per hectare)	376	811	1500
Price (USD per kilogram)	0.96	0.98	0.80
Variable costs			
Seeds	23	76	81
Fertilizers and manure	28	28	70
Plant protection chemicals	6	18	116
Irrigation	2		199
Machinery	40	53	99
Draught animals	24		
Hired labour	63	115	
Family labour	87	39	
Total labour	150	154	
Interest on working capital	6	4	
Levies and insurance			80
Grading and bagging			176
Total variable costs	279	333	822
Gross margin at farm gate			
Gross margin	115	478	678
Gross margin (USD per hectare)	109	468	542

*Gross value of output includes value of crop byproducts.
Source: CACP (2016); Zorya *et al.* (2016); Department of Primary Industries, New South Wales Government.

Table 4.17: Gross value of output, costs and gross margin for urd bean, India and Myanmar (equivalent kilograms of urd bean)

Output, costs and gross margin	India* (2013–14)	Myanmar (2013–14)
Output		
Gross value of output (USD per hectare)	322	474
Yield (kilograms per hectare)	458	757
Price (USD per kilogram)	0.67	0.63
Variable costs		
Seed	32	92
Fertilizers and manure	30	17
Plant protection chemicals	8	18
Irrigation	1	
Machinery and draught animals	96	54
Hired labour	92	131
Family labour	109	45
Total labour	201	176
Interest on working capital	8	4
Levies and insurance	0	
Total variable costs	377	361
Gross margin at farm gate		
Gross margin	101	397
Gross margin (USD per hectare)	68	248

*Gross value of output includes value of crop byproducts.
Source: CACP (2016); Zorya *et al.* (2016).

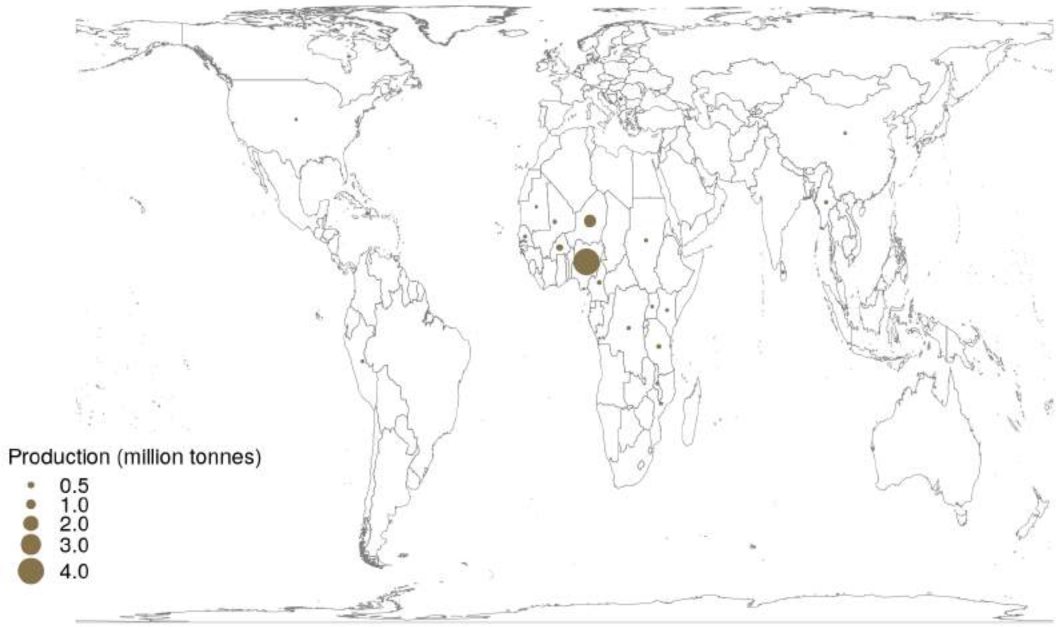
these beans despite a large domestic market. Indian yields are low because of inadequate adoption of improved varieties and agronomic practices. Mung and urd beans are often intercropped with maize, sorghum, cotton and pigeonpea. Given the short maturity period of mung and urd, these are usually the first crops to be harvested from the field. The density of planting of urd and mung beans on such intercropped fields is lower than in fields monocropped with urd and mung. Usage of plant protection chemicals and irrigation is negligible on mung bean farms. Most farmers use local seeds saved by them, and adoption of improved varieties is low.

Cowpea

Cowpea (*Vigna unguiculata L.*) is an arid legume grown in different parts of the world but predominantly in Africa (Figure 4.15). In 2012–14, 7.3 million tonnes of cowpea were produced globally. In the African continent, cowpea production is widespread in Western Africa: Nigeria, Niger and Burkina Faso are the top three producers, and together account for 83 percent of global cowpea production.

Cowpea is a staple food in Africa where, in addition to the grain, the leaves of the plant are also used as a vegetable. It is also commonly used as animal feed. In most major cowpea-producing countries, the crop is primarily cultivated by

Figure 4.15: Production of cowpea across different countries, 2012–14



Source: FAOSTAT data.

small peasant producers who mainly grow it for consumption, intercropping it with cereals. Although there is an increasing trend towards monocropping, intercropping of cowpea with maize, sorghum and pearl millet remains widespread (Monyo and Gowda, 2014).

Cowpea has a high level of resistance to drought and high temperatures, and hence is grown mostly in arid and semi-arid regions where its cultivation is an important strategy to safeguard against drought for small and resource-poor farmers (Peksen, Peksen and Gulumser, 2014).

The average yield of cowpea is low and large yield gaps exist in the major producing countries. In 2012–14, the average yield of cowpea was only 610 kilograms per hectare, although cultivars with yields of 1,500 to 3,000 kilograms per hectare are available. However, despite such continuing low yields, the share of cowpea production in total pulse production increased from 3 percent in 1979–81 to 9.5 percent in 2012–14. This increase was primarily on account of an increase in the area sown with cowpea.

Of all the major cowpea-producing countries, average per hectare yield is the highest (1,115 kilograms per hectare in 2012–14) in Nigeria. In 2012–14, Nigeria produced about 4 million tonnes of cowpea, accounting for a share of 54 percent in global production (Table 4.18). Production of cowpea in Nigeria has increased steadily, at a rate of 5.8 percent, since the 1980s. This was mainly on account of an expansion in the area under cowpea between 1980 and 2000, and entirely on account of yield increases thereafter as the area sown with cowpea started to decline (Figure 4.16).

Niger is the second largest producer of cowpea, with a share of 21 percent in global production. In Niger, the area sown with cowpea has steadily increased, from about 0.5 million hectares in the 1960s to over 5 million hectares in 2012–14. Currently, the country has the largest extent of land under cowpea. However, yields are very low (300 kilograms per hectare in 2012–14) and have been stagnant for the most part of the last five decades (Figure 4.16).

Burkina Faso, the third largest producer of cowpea, produced 0.58 million tonnes of cowpea annually in 2012–14, with an average yield of only about 480 kilograms per hectare. The trends in Burkina Faso also show increasing production, but primarily on account of expansion of area while the yields have been stagnant (Figure 4.16).

Table 4.18: Average annual production, yield and area harvested of cowpea, major producing countries, 2012–14

Country	Production (million tonnes)	Yield (kilograms per hectare)	Area harvested (thousand hectares)	Share in world production (percent)
Nigeria	3.97	1115	3592	54.23
Niger	1.52	300	5051	20.71
Burkina Faso	0.58	480	1216	7.96
Tanzania	0.19	838	224	2.55
Cameroon	0.16	862	205	2.21
Mali	0.15	607	250	2.07
Myanmar	0.13	975	132	1.76
Kenya	0.13	519	248	1.75
Mozambique	0.09	262	342	1.23
Democratic Republic of the Congo	0.08	528	151	1.09
World	7.32	610	12008	100.00

Source: FAOSTAT data.

Since the 1980s, the area under cultivation of cowpea here has increased at an annual rate of 4 percent.

Tanzania ranks fourth in terms of production of cowpea. Although it contributes less than 3 percent to global production figures, it is notable for higher yields (838 kilograms per hectare in 2012–14) than larger producers like Niger and Burkina Faso.

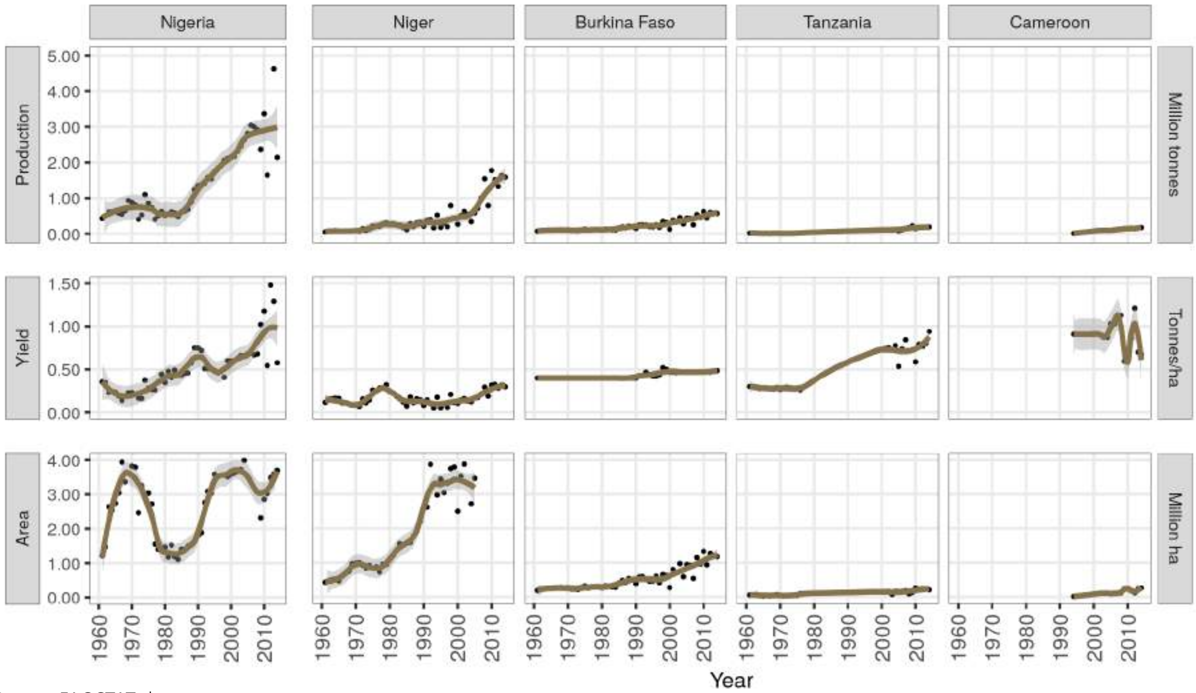
Cameroon is a relatively new player, with cowpea cultivation having started here in the late 1990s. Cameroon exports its cowpea to neighbouring nations, especially Nigeria.

Besides the sub-Saharan countries, Myanmar has emerged as a new producer of cowpea, especially since the early 2000s. With an average yield of 975 kilograms per hectare and 0.13 million tonnes of production in 2012–14, it is the leading producer of cowpea in East Asia.

Yields of cowpea are subject to major biotic and abiotic constraints. Pests, bacterial, fungal and viral diseases, and parasitic weeds, notably *Alectra* and *Striga*, are the major biotic constraints affecting cowpea production. *Striga*, of which the most common species is *Striga gesneriodes*, is widespread in the Sudano-Sahelian region. *Striga* causes yellowing of cowpea leaves and results in huge yield losses. According to Aggarwal and Ouedraogo (1989), the estimated yield loss in West Africa on account of *Striga* is as high as 50 percent across different varieties of cowpea. Maize too is highly vulnerable to *Striga* (Mignouna *et al.*, 2013). A study in northern Nigeria showed that the most common pest that attacks cowpea is *Striga*, and the methods so far used by farmers to deal with it include hand-pulling and ashes. Use of improved varieties did not solve the problem of *Striga* either, mainly because of low resistance (*ibid.*).

Alectra is more prevalent in parts of West Africa, and in East and Southern Africa. Cowpea is often intercropped with cereals, and, in such instances, is also affected by pests like blister beetle and African bollworm. Other important pests include pod borers, aphids and bruchids (Gómez, 2011; Horn, Shimelis and Laing, 2015; Oigiangbe and Nathaniel, 2016; Timko and Singh, 2008).

Figure 4.16: Production, yield and area harvested of cowpea, major producing countries, 1961 to 2014



Source: FAOSTAT data.

Dealing with diseases, pests and parasites has been a major focus of cowpea breeding programmes (Timko and Singh, 2008). Considerable progress has been made in developing varieties resistant to the *Alectra* and *Striga* parasites. However, substantial crop losses are also caused by abiotic stresses. Among them, unreliable rainfall, drought spells of long duration, sand blasts and soil salinity are known to cause considerable damage (Oigiangbe and Nathaniel, 2016; Singh, Mai-Kodomi and Terao, 1999).

Cowpea is more drought-tolerant than crops like soybean and groundnut which are grown in cowpea-producing regions. With its deep tap root system and leaf system adapted to dealing with high temperatures and drought, particularly during the vegetative phase, cowpea can withstand droughts of up to seven to ten days' duration. However, considerable yield losses can occur if there are prolonged spells of drought during the reproductive phase. Cowpea is mainly grown in rainfed conditions in areas where farmers do not have access to irrigation. In view of this, the development of drought-resistant, short-duration varieties has also been an important focus of breeding (Singh and Ajeigbe, 2002).

When intercropped with cereals, cowpea yields are low because of shading of cowpea by the cereal crop. Traditionally, cowpea is planted three to six weeks after sowing of cereals. In such cases, the fast-growing cereal crop shades cowpea and there is increased competition for nutrients (Singh and Matsui, 2002). Apart from improving agronomic practices, shade-tolerant cowpea varieties have been developed to deal with this problem.

Drought-tolerant and *Striga*-resistant short-duration varieties (with a maturity period of about 60 days) of cowpea have been developed under different phases of the Tropical Legume project carried out in fifteen countries in sub-Saharan Africa and South Asia (Monyo, 2013: Monyo and Gowda, 2014; Monyo and Moutari, 2013). Of about eighteen varieties of cowpea that have been released under the Tropical Legumes project, some have been widely adopted (Table 4.19). More progress needs to be made in the production of seeds of improved varieties and in making them available to farmers in cowpea-producing regions (Monyo and Gowda, 2014).

Table 4.19: Varieties developed under the Tropical Legumes project that have been widely adopted

Location	Variety	Characteristics
Nigeria, Mali	IT97K-499-35	Drought tolerance and *Striga* resistance
Niger	IT97K-499-38	High yield
Tanzania	IT00K-1263 and IT99K-1122	Drought tolerance and early maturity
Mozambique	IT00K-1263	Drought tolerance and early maturity

Source: Monyo and Varshney (2007).

In addition to varietal development, agronomic improvements have been recommended for different regions to deal with biotic and abiotic stresses. In the Guinea Savanna zone, traditionally, cowpea, groundnut or soybean are intercropped with cereals, and are planted after three to six weeks of sowing the cereals. This has become unviable now because of shorter fallow periods, competition among crops and increasing demand for food. In view of this, the International Institute of Tropical Agriculture (IITA) recommends strip-cropping of maize and short-duration varieties of cowpea. Intercropping four rows of cowpea after two rows of maize minimizes the shading of legumes by maize. With short-duration varieties, even two successive crops of cowpea can be harvested along with one crop of maize.

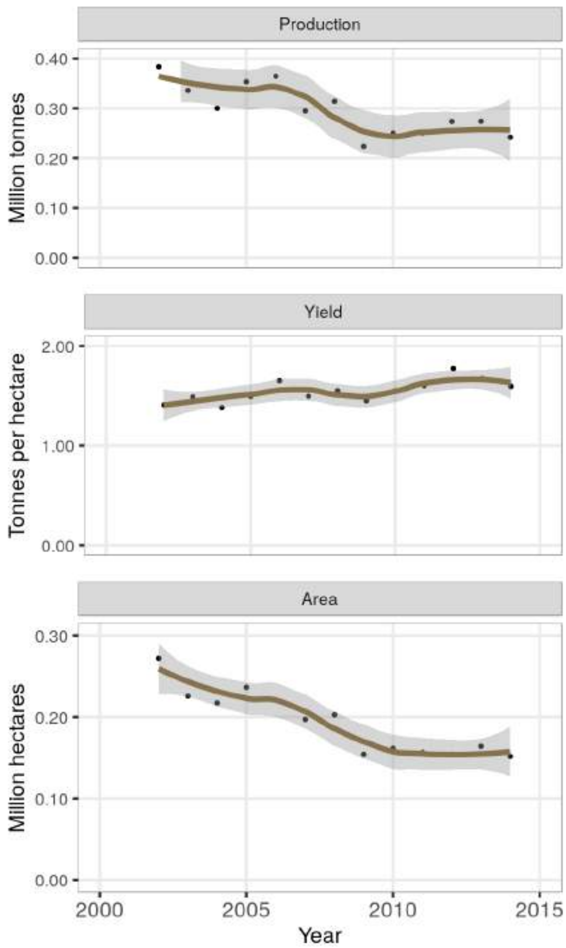
Other Pulses of *Phaseolus* and *Vigna* Genera

Adzuki bean (*Vigna angularis*) is a warm season legume that originated in China, and is currently cultivated in China, Japan, the Republic of Korea and Australia. Moth bean (*Vigna aconitifolia*) is native to India, Pakistan and Myanmar, but is now grown in significant quantities only in arid regions of India.

China is the largest producer of adzuki bean. It is produced there mainly for domestic consumption, with a small quantity being exported to South Korea and Japan. On account of low margins in the production of adzuki bean, the extent of area sown and production figures of the bean have been declining in China (Figure 4.17; also see Li *et al.*, 2016). In 2014, adzuki bean was sown on 152,000 hectares of land in China with an average production of about 0.24 million tonnes. The bean is produced mainly Heilongjian, Tianjin, Hebei, Beijing and Shandong provinces in eastern and northeastern China (Dasgupta and Roy, 2015; Li *et al.*, 2016).

In Japan, adzuki bean is mainly produced in the eastern districts of Hokkaido. In 2007–08,

Figure 4.17: Production, yield and area sown of adzuki bean, China, 2002 to 2014



Source: National Bureau of Statistics of China.

32,600 hectares of land in Japan were used for the production of 65,000 tonnes of adzuki bean.

Outside East Asia, Canada and Australia have started producing adzuki bean in recent years, primarily for exports to East Asia (Hawthorne and Bray, 2011). In 2015–16, Canada exported 14,300 tonnes of adzuki beans to Japan (www.statpub.com).

Moth bean, a *Vigna* bean native to Pakistan, India and Myanmar, is now cultivated to a significant extent only in the arid regions of India (mainly Rajasthan). Moth bean has a very high level of drought and heat tolerance. This short-duration crop is also a rich source of protein, calcium, iron and phosphorus. It is used as a vegetable, as grain and as fodder for livestock (Panwar and Srivastava, 2012). According to data from the Ministry of Agriculture, Government of India, moth bean was grown on 144,000 hectares of land in India between 2009 and 2011.

Bambara bean (*Vigna subterranea*) is a highly drought-resistant legume grown in arid and semi-arid regions of Africa. In 2012–14, Africa produced 0.25 million tonnes of bambara bean. The major producing countries are Mali, Burkina Faso, Cameroon, Niger and the Democratic Republic of Congo.

Commonly known as rice bean, *Vigna umbellate* is mostly found in the tropical areas of the Indian subcontinent (Pratap and Kumar, 2011). It has high resistance to mung bean yellow mosaic virus (MYMV) and bruchids, and is used for crossbreeding with other beans of the *Vigna* genus to introduce resistance into those beans.

Lima bean or butter bean (*Phaseolus lunatus*) is grown in Mesoamerica. In Mexico, this crop is mainly grown in slash-and-burn systems of dryland farming (Martinez-Castillo *et al.*, 2014). After common bean, this is economically the most important bean of the *Phaseolus* genus. Lima bean is on the verge of genetic extinction because of intensification of traditional Mayan agricultural practices, and loss of seed due to abiotic stresses such as drought and hurricanes (Ahuja and Jain, 2015).

There are several species of *Phaseolus* beans that are primarily used now only for introgressing with common bean to transfer disease resistance to the common bean. These include scarlet runner bean (*Phaseolus coccineus*), tepary bean (*Phaseolus acutifolius*) and year bean (*Phaseolus dumosus*). These crops are not produced for human consumption to any significant extent.

Conclusions

This chapter discusses pulses belonging to two different genera: *Phaseolus* and *Vigna*. Together, about 32 million tonnes of different types of pulses that belong to these two genera were produced globally in the triennium ending 2014. This accounted for about 41 percent of global pulse production. *Vigna* pulses are mainly produced in Asia and Africa, while *Phaseolus* beans are produced mainly in the Americas, Africa and Europe. These pulses are important for dryland agriculture, particularly in Africa and Asia.

Of the various types of pulses discussed in this chapter, there has been significant growth in the production of common bean and cowpea between 2001 and 2014. For both these crops, the growth has come primarily from an expansion of cultivation in sub-Saharan Africa. The total production of *Phaseolus* and *Vigna* pulses in sub-Saharan Africa increased from 6.3 million tonnes in the triennium ending 2001 to 13 million tonnes in the triennium ending 2014. Although the area under common bean in the major Latin American countries has fallen in recent years, improvements in yields have helped sustain production. Southeast Asia and Australia have been important regions of growth in production of mung and urd beans.

Growth in production of these pulses has been made possible because of considerable research efforts, led by CIAT and national-level institutions in Brazil, India, China and Australia. CIAT has established strong collaborative networks in Latin America, Africa and South Asia. Major successes in research and its extension to the field have come about in the case of common bean and cowpea. In contrast, production of mung and urd beans has stagnated in India and China, which are the major producers of these beans. Although some research has been done at the national level in India to develop short-duration varieties of mung and urd beans for introduction as third crops in the Indo-Gangetic belt, a stronger push in research and extension is required to make this popular.

A review of the data shows that returns from cultivation of these pulses on smallholder farms are low. This has been an important factor behind the stagnation of production of *Phaseolus* and *Vigna* beans in South Asia and Latin America. Large-scale commercial farms in Australia, the United States and Brazil have higher yields and gross margins than smallholder producers because of greater adoption of both improved varieties and modern agronomic practices. Among these countries, production (of mung bean) has expanded in Australia; production has not expanded in the United States and Brazil, however, because of lower gross margins in the cultivation of common bean than of competing crops.


HORSE

LENTIL: EMERGENCE OF LARGE-SCALE, EXPORT-ORIENTED PRODUCTION

Vikas Rawal and Vaishali Bansal

Overall Trends in Production and Trade

Lentil (*Lens culinaris*) is a self-pollinating, cool season pulse crop. It is cultivated in sub-tropical and warm temperate regions, and on high altitudes in the tropics. In 2012–14, about 4.3 million hectares of land were under lentil globally and average annual production of lentil was about 5 million tonnes.

The last three decades have seen a major shift in the distribution of global production of lentil, with new countries – most notably, Canada and Australia – entering into lentil production. These countries today count among the largest producers of lentil. Lentil cultivation in these countries is carried out on large-scale, capital-intensive farms, and is characterized by high yields.

Figure 5.1 shows the global trends in production, area and yield of lentil. The most striking feature of the graph is the emergence of Canada as the largest producer of lentil over the last two decades. Currently, Canada accounts for about 40 percent of the world's total production of lentil. India is the second largest producer, accounting for about 22 percent of global production. Turkey, Australia, Nepal and the United States of America (USA) are the other significant producers of lentil (Table 5.1, Figure 5.2). Between 2000 and 2014, lentil production in Canada and Australia grew rapidly. In sharp contrast, lentil production either stagnated or declined in most other major lentil-producing countries.

Both Canada and Australia produce lentil primarily for exports. As can be seen from Table 5.2, in 2011–13, 77 percent of lentil produced in Canada and 82 percent produced in Australia were exported; in the same period, 61 percent of the lentil traded globally originated in Canada and 14 percent originated in Australia. The share of lentil produced in the USA, which also produces the pulse primarily for exports, in global trade was 8 percent.

Lentil is imported by and consumed widely in many Asian and European countries. As seen in Table 5.3, India accounts for 19 percent of

Table 5.1: Average production, yield and area harvested of lentil, major producing countries, 2012–14

Country	Production (million tonnes)	Yield (kilograms per hectare)	Area harvested (thousand hectares)	Share in world production (percent)
Canada	1.9	1743	1091	38.3
India	1.1	722	1520	21.8
Turkey	0.4	1570	256	8.1
Australia	0.4	2011	192	7.6
Nepal	0.2	1068	207	4.4
United States of America	0.2	1466	142	4.2
China	0.1	2218	67	3.0
Ethiopia	0.1	1293	116	3.0
Bangladesh	0.1	420	258	2.2
Syrian Arab Republic	0.1	905	118	2.2
World	5.0	1145	4333	100.0

Source: FAOSTAT data, updated using national statistics.

the world's imports, Turkey for 10 percent and Bangladesh for 7 percent.

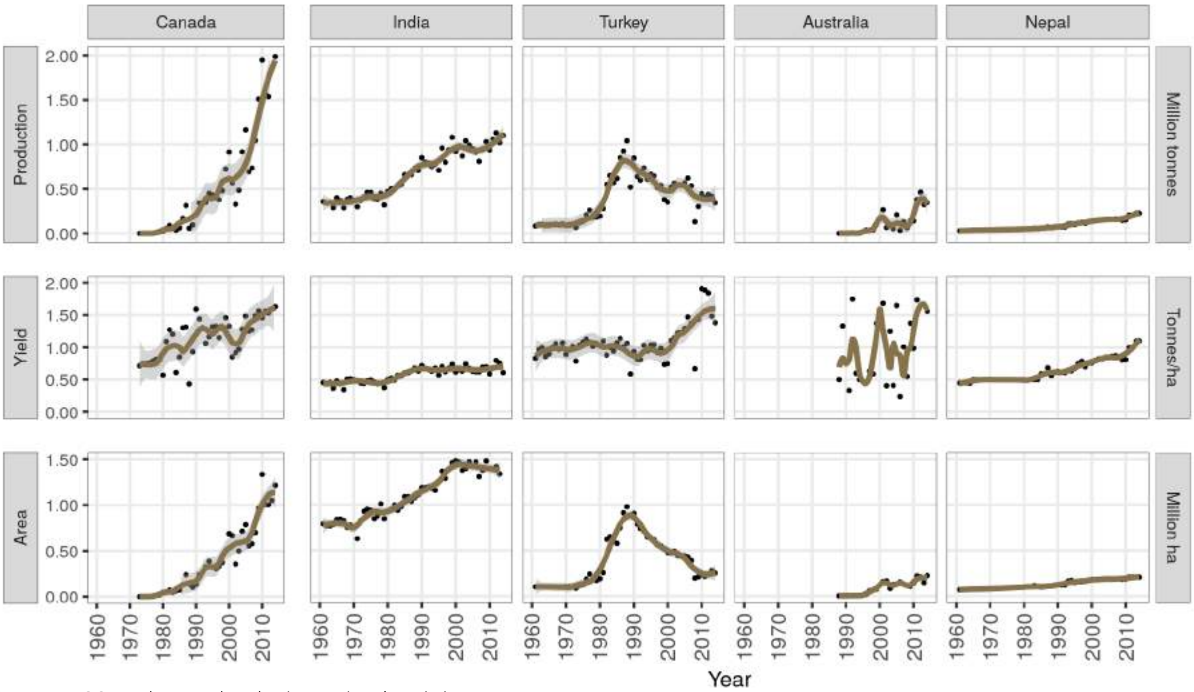
Lentil is cultivated as a sole crop in sequential crop rotation cycles, or as part of mixed-cropping or intercropping systems, or in multistoreyed cropping systems along with tree crops (Table 5.4). In both Canada and Australia, two countries with large-scale, capital-intensive production of lentil, the average national yield has been about 2 tonnes per hectare in recent years (Figure 5.1). In contrast, the yields are much lower in countries where lentil is cultivated primarily on small holdings.

The establishment of the International Center for Agricultural Research in the Dry Areas (ICARDA) in 1977 was an important landmark globally for breeding research on lentil. ICARDA has played a crucial role in developing, classifying and evaluating germplasm accessions of lentil. It presently holds 11,877 lentil accessions (ICARDA, 2014).

An early finding of ICARDA's evaluation was that lentil germplasm in South Asia, the region with the highest production figures for lentil, had a very narrow genetic base. South Asian varieties of lentil all belonged to the *pilosae* group, with high sensitiveness to temperature and low responsiveness to photoperiod. Erskine *et al.* (1998) have argued that this narrow genetic base of South Asian lentil was a result of the inability of West Asian varieties to flower soon enough in the agroclimatic conditions of South Asia. In view of this, a major focus of ICARDA has been to collaborate with national research institutions in Bangladesh, Pakistan and India in order to improve the genetic diversity of lentil in South Asia by introducing early maturing varieties from West Asia, through hybridization and selection, and mutation breeding (Erskine *et al.*, 1998; Materne and McNeil, 2007). Developing short- and medium-duration, high-yielding and disease-resistant varieties suitable to South Asian conditions has been made possible because of the introduction of West Asian germplasm into South Asia. Yield improvements in Nepal and Bangladesh especially are a direct outcome of these measures.

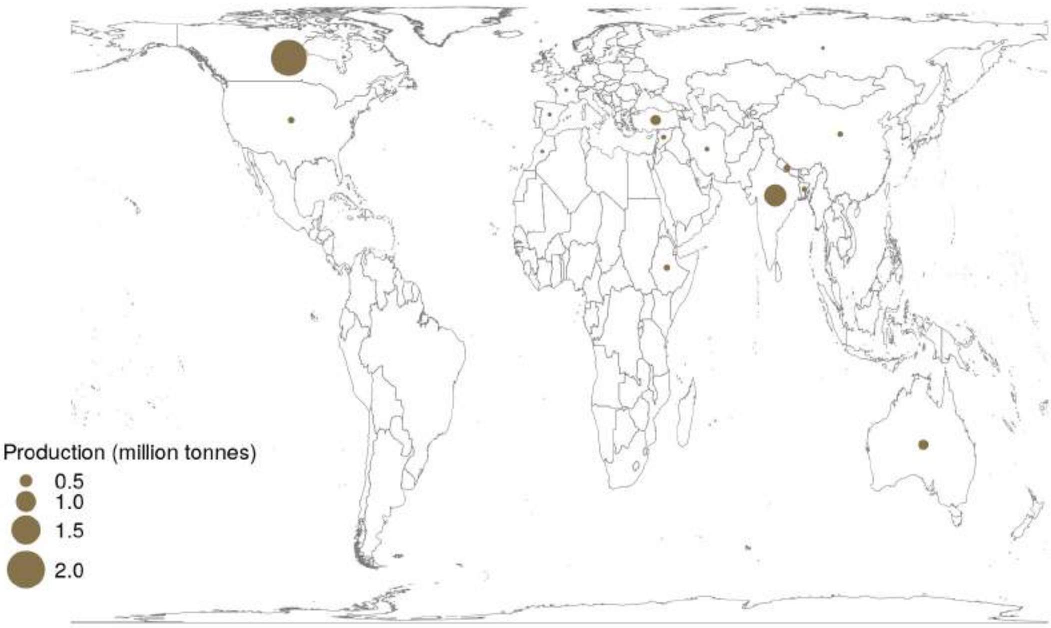
ICARDA's germplasm lines have been used to develop improved varieties of lentil in all the major producing countries. These include not

Figure 5.1: Production, yield and area harvested of lentil, major producing countries, 1961 to 2014



Source: FAOSTAT data, updated using national statistics.

Figure 5.2: Production of lentil across different countries, 2012–14



Source: FAOSTAT data, updated using national statistics.

just the traditional lentil-growing countries in West Asia and South Asia, but also new lentil-producing countries like Canada and Australia, where prolonged research was required to identify and select suitable varieties with optimal physiological responses in the agroclimatic conditions prevalent in those regions.

Lentil breeding has focused on developing varieties with optimal phenology for different lentil-growing regions, developing varieties

Table 5.2: Annual exports, share in world exports and ratio of exports to production of lentil, major exporting countries, 2011–13

Country	Exports (thousand tonnes)	Share in world exports (percent)	Ratio of exports to production (percent)
Canada	1364	61	77
Australia	319	14	82
Turkey	196	9	47
United States of America	185	8	81
World	2230	100	46

Source: FAOSTAT data.

Table 5.3: Annual imports and share in world imports of lentil, major importing countries, 2011–13

Country	Imports (thousand tonnes)	Share in world imports (percent)
India	408	19
Turkey	226	10
Bangladesh	155	7
Sri Lanka	139	6
United Arab Emirates	139	6
Egypt	84	4
Algeria	74	3
Colombia	63	3
Pakistan	75	3
Iraq	51	2
Spain	51	2
France	28	1
Germany	25	1
Italy	30	1
Lebanon	11	1
United Kingdom	24	1
World	2181	100

Source: FAOSTAT data.

tolerant to abiotic stresses and resistant to diseases, and developing varieties that can be mechanically harvested (Materne and McNeil, 2007). Drought and heat are the biggest abiotic constraints to raising lentil yields. In parts of the Indian subcontinent, North Africa, West Asia and Saskatchewan (Canada), high soil salinity also poses a problem.

Ascochyta blight, *Botrytis* grey mould and *Fusarium* wilt, all caused by fungi, are the most important diseases afflicting lentil. In the past, these have caused massive damage to the crop

Table 5.4: Important lentil-based cropping systems reported in studies of different lentil-growing regions

Cropping system	Countries from where reported
Mixed cropping	
Wheat + lentil	Bangladesh (Mymensingh), Turkey (Van)
Linseed + lentil	India (Uttar Pradesh), Turkey (Van)
Barley + lentil	Turkey (Van)
Sequential cropping	
Lentil – finger millet	India (Uttar Pradesh)
Lentil – wheat	Iran (Kermanbshan)
Rice – lentil	India (Uttar Pradesh, Uttarakhand, West Bengal)
Soybean – lentil	India (Madhya Pradesh)
Wheat – lentil	Syria
Lentil – canola	Canada (Saskatchewan)
Lentil – mustard	Canada (Saskatchewan)
Lentil – durum wheat	Canada (Saskatchewan)
Intercropping	
Sugarcane (autumn) + lentil	India (Uttarakhand, West Bengal)
Wheat + lentil	USA (Dakota), Egypt (El-Gemmeiza), Pakistan (Dera Ismailkhan), Bangladesh (Mymensingh)
Lentil + linseed	India (West Bengal, Uttar Pradesh)
Lentil + mustard	India (Bihar, West Bengal, Uttar Pradesh)
Chickpea + lentil	Pakistan (Punjab)
Barley + lentil	Central Europe
Maize + lentil	India (Uttar Pradesh)
Utera (relay) cropping	
Rice + lentil	India (Madhya Pradesh), Pakistan (Faizabad)
Multistorey cropping	
Shisham + lentil	India (Haryana)
Eucalyptus + lentil	India (Haryana)

Source: Sekhon, Singh and Ram (2007).

across most lentil-growing countries. Although lentil varieties that are resistant to these diseases have been developed, their adoption in countries characterized by smallholder lentil production is low (Erskine *et al.*, 1994; Materne *et al.*, 2007; Muehlbauer *et al.*, 2006; Taylor *et al.*, 2007).

Lentil does not compete well with weeds and most varieties have low levels of herbicide tolerance (Brand *et al.*, 2007). In countries with large-scale lentil farming, pre-sowing and pre-emergence herbicide applications are the major strategies for dealing with weeds. In smallholder farms, manual weeding is the most important strategy. A combination of pre-sowing or pre-emergence application of herbicides and manual weeding are recommended as the most effective means of dealing with weeds. Developing herbicide tolerance in lentil is an important focus of current breeding research.

Another focus of breeding research in lentil in recent times has been to identify and release micronutrient-dense varieties, particularly in South Asia. Eleven biofortified varieties of lentil with high concentrations of iron and zinc have been released in Nepal, Bangladesh and India through partnerships between ICARDA and national research centres (Della Valle *et al.*, 2013; ICARDA, 2015; Kumar *et al.*, 2016b).

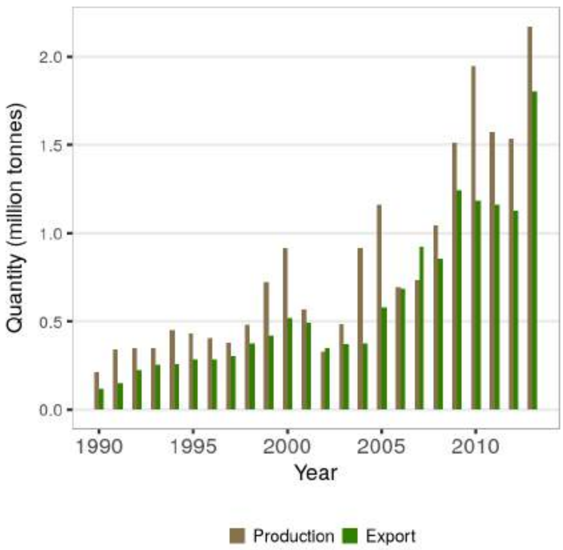
Canada

Canada is the largest producer of lentil, with a total production figure of about 2 million tonnes in the triennium ending 2014. Lentil in Canada is primarily produced in Saskatchewan, which accounts for about 90 percent of the country's total lentil production. Lentil is also produced in Alberta and Manitoba, in areas neighbouring Saskatchewan (Yadav *et al.*, 2007a).

Canada started producing lentil in the 1970s. The development of Laird, a large-seeded green lentil variety, and Eston, a small-seeded green lentil variety, and their widespread adoption was behind the growth of lentil production in this phase. From the 1970s through the 1990s, Canada primarily produced green lentil. The push for expansion of lentil farming in the country was a result of significant public investment in breeding suitable varieties of lentil, and of developing suitable agronomic practices and extension services. The government of Saskatchewan provided core funding for setting up the Crop Development Centre (CDC) at the University of Saskatchewan in 1971. CDC played a crucial role in catalysing the growth of lentil production in Canada: apart from identifying suitable cultivars like Laird and Eston, the Centre also provided support by way of researching and documenting the best agronomic practices and making these available to cultivators. Rhizobium inoculants were developed to accelerate nitrogen fixation and keep input costs low in cultivation. Since the late 1970s, controlling diseases that afflict lentil – by releasing suitable chemicals for treatment as well as developing varieties resistant to these diseases – has also emerged as an important focus of work at CDS.

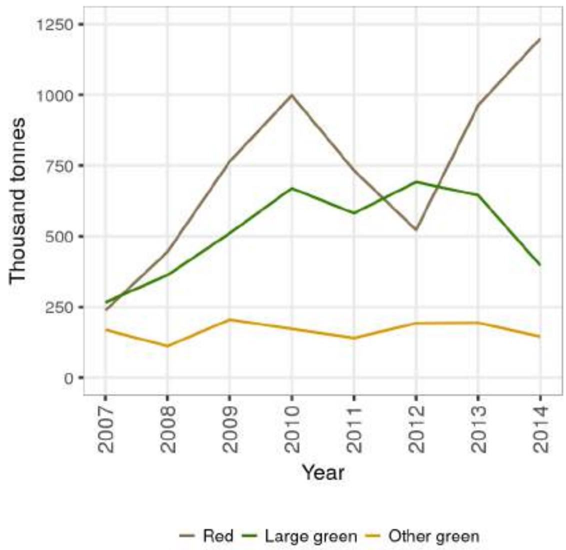
The Saskatchewan Pulse Crop Growers Association (SPCGA) was formed in 1976. Following this, the SPCGA, CDC and Extension Department of the government of Saskatchewan

Figure 5.3: Production and exports of lentil in Canada, 1990 to 2013



Source: FAOSTAT data.

Figure 5.4: Production of different types of lentil in Saskatchewan, 2007 to 2014



Source: Data from Government of Saskatchewan.

worked together to provide information about lentil production to growers. In 1983, the Saskatchewan Pulse Crop Development Board, later renamed as the Saskatchewan Pulse Growers (SPG), was established.

In 1984, the SPG decided to impose a mandatory levy of 0.5 percent of gross value of sale on lentil growers, which was later increased to 1 percent. The levy, collected by companies buying the pulse from growers, was used to fund research at CDC on agronomic practices and breeding of suitable varieties. State and national governments provided matching grants for investments made by the SPG in CDC. Given the large scale of the lentil industry in Canada, levy collections have proved to be a substantial and stable source of funds for research. In 2015, the SPG collected CAN$ 18 million in levy (Growers, 2015).

McVicar *et al.* (2000) point out that the removal of transport subsidies to agriculture in the mid-1990s propelled farmers to grow higher-value crops in order to reduce the share of freight cost per unit of grain transported. Since the 1990s, there has also been a consolidation of primary processing in large-scale plants for cleaning, packaging and transporting lentil.

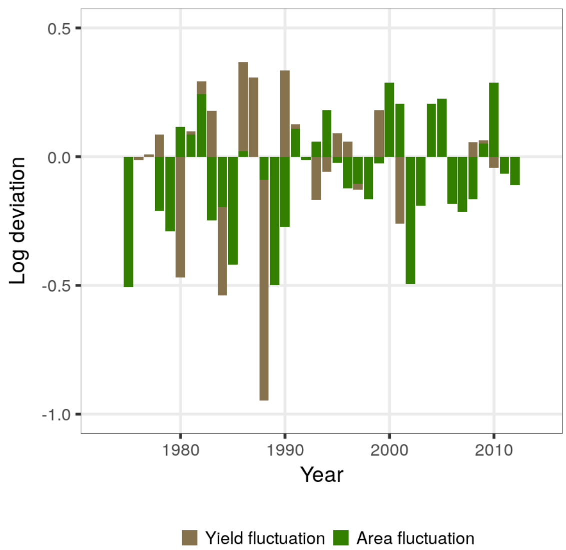
With large-sized farms, Canadian lentil production is fully mechanized and technologically advanced. In 2011, 80 percent of the farms in Canada reported use of no-till seeding, 90 percent used herbicides, 40 percent used fungicides and 90 percent used chemical Fertilizers (Bekkering, 2014a).

Lentil produced in Canada is primarily for exports (Figure 5.3). The domestic demand for lentil is very small, mainly for use as livestock feed. Over the decade of the 1990s, India emerged as a major importer of pulses globally. However, the demand for lentil in the Indian subcontinent is primarily for the red variety and not the green variety. In view of this, the focus of research in Canada shifted in the 1990s to breeding varieties of red lentil, and production of red lentil registered steady growth. By the end of the 1990s, Saskatchewan had developed high-yielding, disease-resistant and machine-harvestable varieties of red lentil. In 2014, about 69 percent of lentil produced in Saskatchewan was of the red variety (Figure 5.4).

It is interesting to note, however, that India also imported a substantial quantity of green lentil from Canada: between 2012–13 and 2015–16, 22 percent of Canadian exports of green lentil went to India. Green lentil, which has yellow cotyledons, is imported by India in order to adulterate pigeonpea after dehulling and splitting. Besides India, large-type green lentil is also exported from Canada to northwestern and southern Europe, northern Africa, South America and Central America. Medium-type green lentil is exported to the US, northwestern Europe, Spain and northern Africa. The small green lentil is exported to Morocco, Greece, Italy, Egypt and Mexico.

Lentil production in Canada, when it started in the 1970s, was relatively disease-free. Storage pests were not a serious problem either, because of the severe winter cold. *Ascochyta* blight of lentil, transmitted to Canada through imports of infected seeds from the Pacific northwest of the USA, was first reported in 1978 and has since become a serious issue (Morrall, 1997; Morrall and Sheppard, 1981). Morrall (1997) pointed out that the spread of *Ascochyta* blight was particularly high in Canada because, unlike

Figure 5.5: Deviation from logs of area and yield of lentil from five-year moving averages, Canada, 1975 to 2012



Note: The graph shows deviation of logs of area and yields from five-year moving averages.
Source: FAOSTAT data.

in traditional lentil-growing areas, the weather here at the time of maturity of the lentil crop was still cool and rainy. Further, mechanized harvesting and swathing of lentil contributed to spread of the disease. As seen in Figure 5.5, high yield fluctuations in the 1980s in Canada were a result of widespread occurrence of *Ascochyta* blight. *Anthracnose* and *Botrytis* stem and pod rot are other lentil diseases widely prevalent in the country.

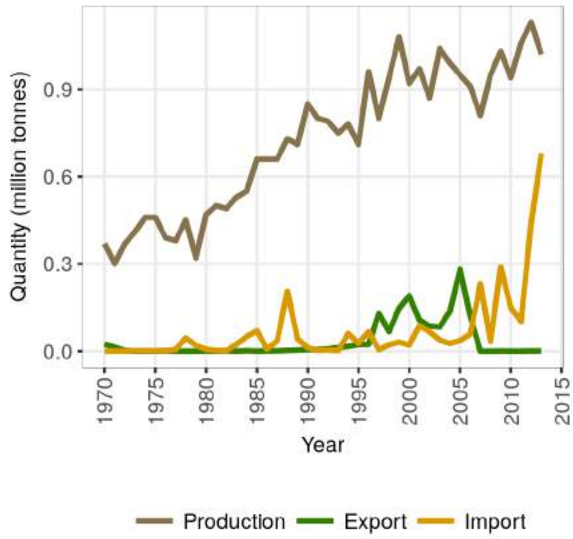
Many cultivars and wild varieties of lentil resistant to *Ascochyta* blight, as well as genes responsible for resistance, have been identified (Tullu *et al.*, 2010; Ye, McNeil and Hill, 2002). At least in some conditions, the pathogen causing *Ascochyta* blight in lentil is known to have increased in its virulence, and varieties known to possess resistance have been affected (Davidson *et al.*, 2016). While several *Ascochyta*-resistant varieties have been released in different countries, further research is in progress to develop varieties that will be resistant in diverse environments.

India

India is the second largest producer and the largest consumer of lentil in the world. In 2013–14, India produced about 1 million tonnes of lentil. In addition to the lentil it produces, which is largely directed towards domestic consumption, India also imports lentil, mainly from Canada. There has been a substantial rise in Indian imports of lentil since 2007 (Figure 5.6). In 2013, the latest year for which trade data are available, India imported 0.7 million tonnes of lentil. It is estimated that the shortfall between the demand for lentil for direct consumption and the domestic supply of lentil in India is about 0.3 million tonnes. Apart from its imports of red lentil, India has also been importing a substantial quantity of large green lentil in recent years, for use as dehulled and split seeds mixed with pigeonpea.

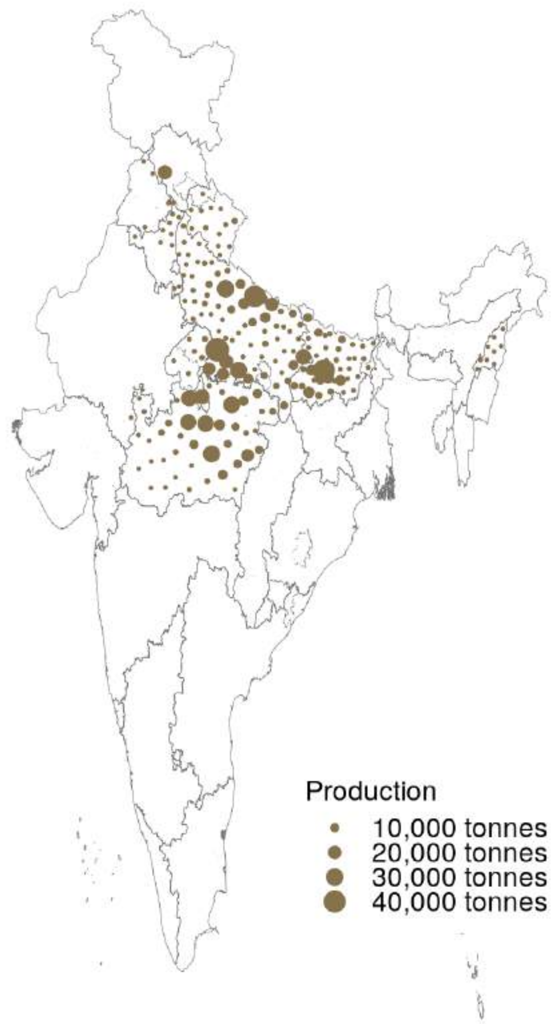
The yield levels of lentil in India are very low. Table 5.1 shows that the average yield in India in 2012–14 was less than 800 kilograms per hectare, lower than that of all major lentil producing countries of the world. Reddy and Reddy (2010) analysed the gaps between farmers'

Figure 5.6: Production, exports and imports of lentil in India, 1970 to 2013



Source: FAOSTAT data, updated using national statistics.

Figure 5.7: Production of lentil in India, 2009–10



Source: Data from the Ministry of Agriculture, Government of India.

yields and yields obtained in research stations in three lentil-growing zones in India (the north hill zone, northwest plain zone and northeast plain zone). They found that the farmers' yields were between 46 to 62 percent of the yields obtained in research stations in these zones.

Production of lentil in India is concentrated in eastern Uttar Pradesh, Chhattisgarh, Bihar and West Bengal (Figure 5.7). According to the national survey on cost of production, in 2010, 95 percent of the holdings on which lentil was cultivated had sown less than 1 hectare of land with the pulse crop.

Lentil cultivation in India is characterized by low yields. This is because the pulse is produced mainly on tiny holdings with marginal soils, and under rainfed conditions. Most cultivators grow nondescript, farmer-preserved varieties of lentil, and adoption of improved varieties is miniscule in extent. Although the yields of some of these local cultivars are good under normal agroclimatic conditions, they drop substantially under conditions of drought, heat or biotic stresses. Poor agronomic practices – lack of irrigation, lack of proper weed management, poor management of nutrients and inability to deal with diseases – also cause significant yield losses.

While Indian production of lentil continues to be characterized by considerable yield gaps, it must be pointed out that considerable scientific work has been done to improve lentil yields. Research on lentil in India is organized under the All India Coordinated Research Project on MULLaRP of the Indian Council of Agricultural Research (ICAR). Until the 1970s the studies were primarily focused on pureline selection from land races and testing in different locations. Since the 1980s the focus has shifted to using hybridization and mutation to develop improved varieties.

While many improved lentil varieties suited to different agroclimatic regions have been developed, large gaps remain in making them available to farmers. Under the ICAR project, 558 quintals of breeder seeds of 31 improved varieties were produced in 2015–16. With such a scale of production, a considerable quantity of certified seeds, sufficient to cover about 15 percent of the area under lentil in a year, can be produced for distribution among farmers. However, poorly administered systems of seed production and distribution at the level of the state governments result in very limited dissemination and adoption of improved varieties.

Turkey

There is a large domestic market for lentil in Turkey. Turkish lentil farms are primarily family farms. While they are not as large as the industrial-scale lentil farms in Canada or Australia, they are bigger than the tiny holdings on which lentil is cultivated in South Asia. About 80 percent of lentil producers in Turkey have farms that are more than 5 hectares in size (Yadav *et al.*, 2007a). Lentil is mainly produced on unirrigated holdings in Turkey.

Three distinct phases can be identified in the contemporary history of lentil production in Turkey, as follows.

The decade of the 1980s

The decade of the 1980s was characterized by a dramatic expansion of lentil production in Turkey, as a result of an increase in the land under lentil cultivation. This was primarily a result of bringing large tracts of fallow land into annual cropping cycles under the Utilization of Fallow Areas Project initiated in 1982. As reported by Açikgöz *et al.* (1994), 1.4 million hectares of fallows were brought under cultivation in the first phase of this project, and 1.7 million hectares in the second phase.

Although yields were stagnant, the expansion of land under cultivation to fallows resulted in a sharp increase in lentil production. By the end of the decade, Turkey emerged as one of the largest producers of lentil in the world with an annual production figure of about 1 million tonnes.

Historically, Turkey had mainly produced red lentil. The 1980s witnessed an expansion of green lentil production, and by the end of that decade, Turkey was producing about 0.2 million tonnes of green lentil.

The decade of the 1990s

While the 1980s were marked by a large expansion of the land under lentil production, the following decade saw an equally dramatic collapse: continued stagnation of yields was accompanied by a shift of land away from lentil cultivation.

It is noteworthy that Canada emerged as a major global producer of green lentil in the same period. In the face of competition from Canada, production of green lentil in Turkey declined from about 0.2 million tonnes at the start of the 1990s to only about 60,000 tonnes by the end of the decade. During this period, a part of the green lentil imported by Turkey from Canada was re-exported to the Middle East and India. This, however, ceased by the end of the decade (McNeil *et al.*, 2007).

The yields of lentil over this period remained stagnant, at an average of 967 kilograms per hectare for red lentil and 808 kilograms per hectare for green lentil. On the other hand, the area under cultivation of red lentil fell from 0.63 million hectares in 1990 to 0.42 million hectares in 1999. The area under green lentil fell even more dramatically, to one-third: from 0.27 million hectares in 1990 to only 97,000 hectares in 1999. The stagnation of yield was a result of drought, lack of availability of herbicides to control weeds, and low adoption of improved varieties (Açikgöz *et al.*, 1994).

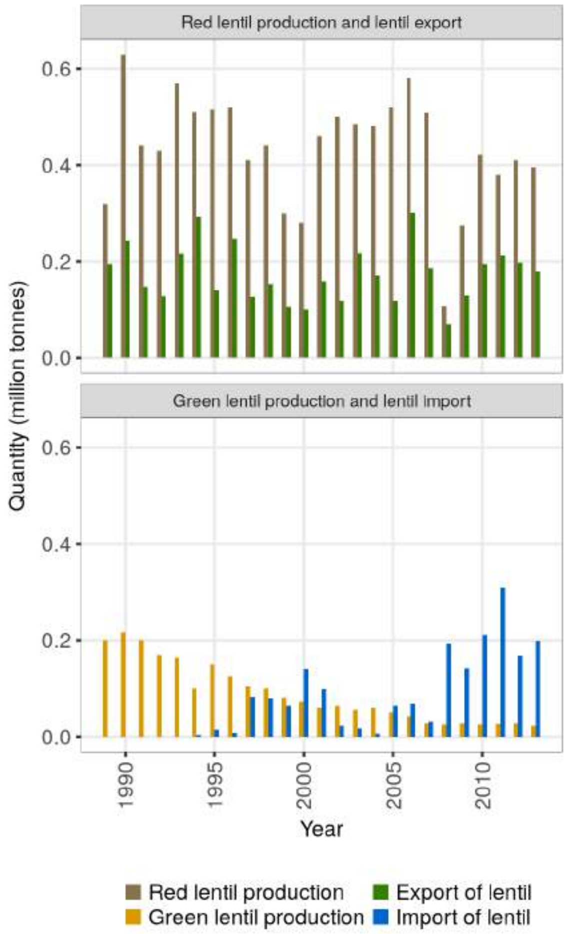
The period after 2000

The period after 2000 continued to be marked by a shift away from lentil production, but was distinct from the 1990s in two respects.

With Canada diversifying into red lentil production and the expansion of red lentil farming in Australia, the export market for Turkish red lentil shrank (Figure 5.8). By 2015, the area under red lentil fell to 200,000 hectares. At the same time, land under green lentil cultivation continued to fall and declined to only 16,000 hectares.

Although there was a decline in the area sown with red and green lentil in the post-2000 period, there was a significant improvement in lentil yields in this phase, in contrast to the earlier phases. The Turkish research programme on lentil, which started in the mid-1970s, witnessed a harnessing of synergies with global efforts for developing improved varieties and modern agronomic practices. By the end of the 1990s, many improved varieties had been developed that were suited to the agroclimatic conditions of the lentil-growing areas of Turkey (Açikgöz *et al.*, 1994). Better agronomic practices for weed control and cultivation of improved varieties were widely adopted in the post-2000 period, which resulted in considerable rise in yields. Between 2010 and 2015, the average yield of red lentil in Turkey was 1,739 kilograms per hectare and of green lentil, 1,158 kilograms per hectare.

Figure 5.8: Production, exports and imports of lentil in Turkey, 1989 to 2013

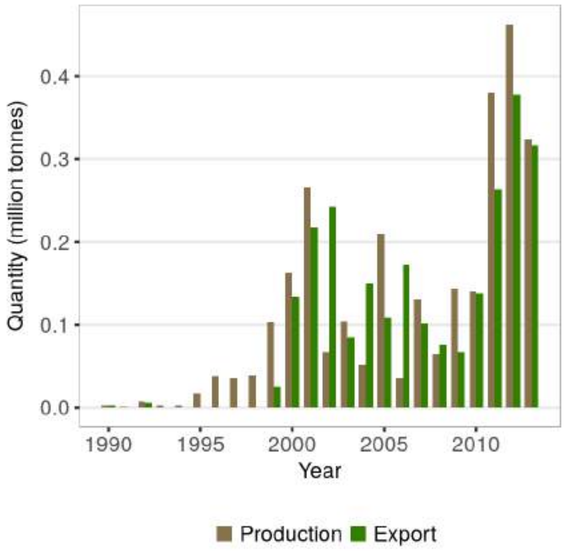


Note: Turkey mainly exports red lentil and imports green lentil. However, annual data on exports and imports are not available separately by type of lentil.
Source: Based on data from Turkish Statistical Institute (http://www.turkstat.gov.tr) and FAOSTAT.

Australia

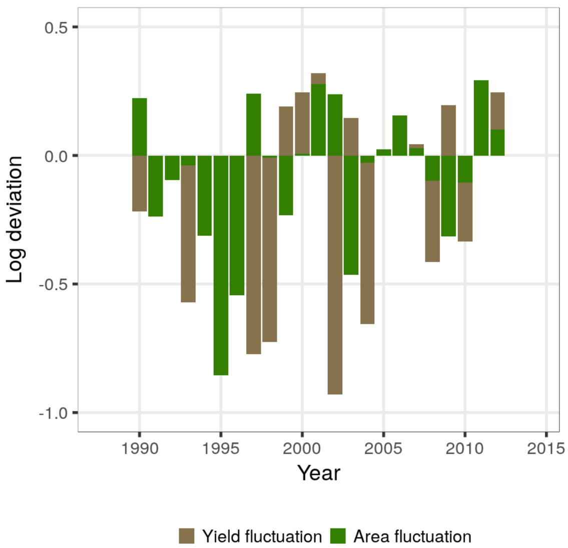
In Australia, lentil is cultivated primarily in the states of Victoria and South Australia, where it is part of a crop rotation cycle dominated by wheat. In any given year, only about 2–3 percent of the

Figure 5.9: Production and exports of lentil in Australia, 1990 to 2013



Source: FAOSTAT data, updated using national statistics.

Figure 5.10: Deviation from logs of area and yields of lentil from five-year moving averages, Australia, 1990 to 2012



Note: The graph shows deviation of logs of area and yields from five-year moving averages.
Source: FAOSTAT data updated using national statistics.

arable land of these two states is sown with lentil.

During 2012–14, the average annual production of lentil in Australia was 378,000 tonnes. About 90 percent of the lentil produced in the country is red lentil. Domestic consumption of lentil is small in Australia and it is produced mainly for export: 78 percent of Australian lentil is exported to the Indian subcontinent (Figure 5.9; Pulse Australia, 2015).

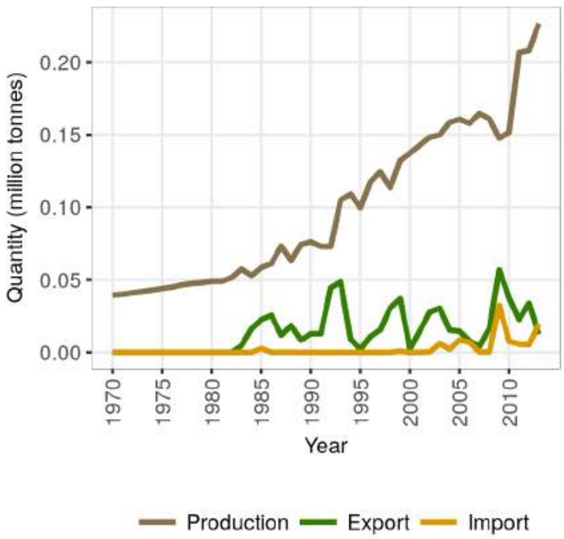
Lentil is a relatively recent crop in Australia with substantial cultivation having started only from around the mid-1990s. Materne and Reddy (2007), who provide a historical account of the development of lentil farming in Australia, say that lentil production picked up in the country after the introduction of improved varieties that were suited to agroclimatic conditions, disease-resistant and machine-harvestable, acquired from the International Center for Agricultural Research in the Dry Areas (ICARDA). They point out that promotion of agronomic practices like early harvesting, mechanical improvements to prevent harvest losses and weed control also played a crucial role in the widespread adoption of lentil farming. In the early years, Australian exporters had to face adverse market conditions because of the poor quality of mechanically harvested Australian lentil and the established export network of Canada and Turkey. In 1992, it was found that red vetch, which had similar physical characteristics, was being exported from Australia as lentil. This led to the imposition of import restrictions on Australian lentil in India, Egypt and Saudi Arabia (Tate and Enneking, 1992). In 1999, the Australian government introduced mandatory inspection and phytosanitary certification to prevent the sale of red vetch as lentil (Tate *et al.*, 1999).

Lentil production in Australia is subject to large fluctuations (Figure 5.10). The extent of area sown with lentil varies in response to export demand and accumulation of carry-over stocks. Until the mid-2000s, there were also large fluctuations in yield because of high exposure to drought and biotic stresses. With improvements in breeding and use of better agronomic practices, yield fluctuations have declined considerably in recent years.

Nepal

Lentil is the most important pulse crop cultivated in Nepal. In 2012–14, it accounted for 73 percent of the country's total production of pulses. Lentil is produced in Nepal mainly for domestic consumption, though a small part is also exported (Figure 5.11). Bangladesh is Nepal's biggest

Figure 5.11: Production, exports and imports of lentil in Nepal, 1970 to 2013



Source: FAOSTAT data.

trading partner for lentil, accounting for over 80 percent of exports from Nepal (ANSAB, 2011).

Lentil production in Nepal has seen a steady growth since the 1960s (Figure 5.1 and Table 5.5). Area under cultivation of lentil increased steadily from 70,000 acres in the triennium ending 1963 to 207,000 hectares in the triennium ending 2014. This was primarily a result of the expansion of lentil cultivation to rice fallows in the Terai region. Restrictions imposed on cultivation of grasspea in the early 1990s induced farmers to grow lentil instead. Cultivators preferred lentil over chickpea because of the greater susceptibility of chickpea to diseases and pests. Wheat, another alternative crop for rice fallows, was not preferred over lentil either, because it involved a higher cost of production and required access to irrigation. The rising price of lentil also contributed to making it an attractive option for farmers (Yadav *et al.*, 2007a). Since the 1980s, there has also been a steady increase in the yields of lentil in Nepal. In 2012–14, the average yield was more than 1 tonne per hectare.

Bangladesh

In terms of human consumption, lentil is one of the most important pulses cultivated in Bangladesh (Sarker *et al.*, 2004). It is primarily grown in the southwestern part of the country, in rice fallows in winter (Figure 5.12).

Pulse production in Bangladesh faces a high degree of competition from cereals and oilseeds, as a result of which area sown with lentil has declined significantly since the 1980s. As can be seen from Table 5.6, land under lentil declined from 292,000 hectares in the triennium ending 1980 to only 182,000 hectares in the triennium ending 2010; and production of lentil fell from 172,000 tonnes in the triennium ending 1980 to 68,000 tonnes in the triennium ending 2010.

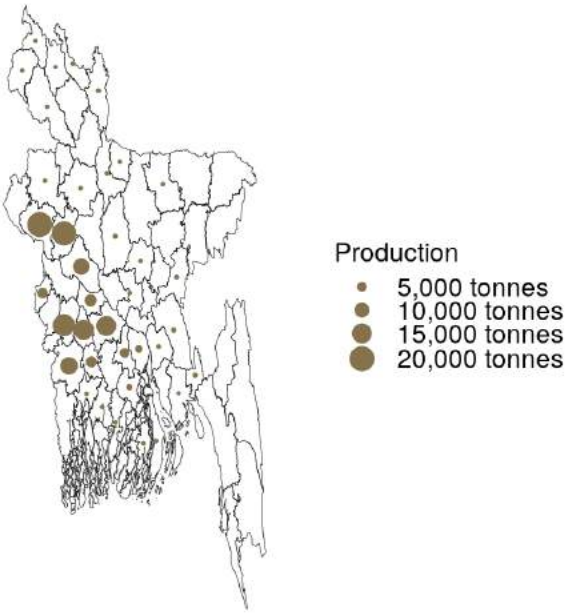
This long-term trend of decline in lentil production was reversed in recent years with the introduction of high-yielding varieties. The increase in lentil yields is a result of a successful programme of collaboration between the Bangladesh Agricultural Research Institute (BARI) and ICARDA. As a part of this programme,

Table 5.5: Average production, yield and area of lentil in Nepal, 1963 to 2014

Triennium ending	Area (thousand hectares)	Yield (kilograms per hectare)	Production (thousand tonnes)
1963	70	450	32
1971	79	500	40
1981	98	497	49
1991	121	618	75
2001	178	773	138
2014	207	1068	221

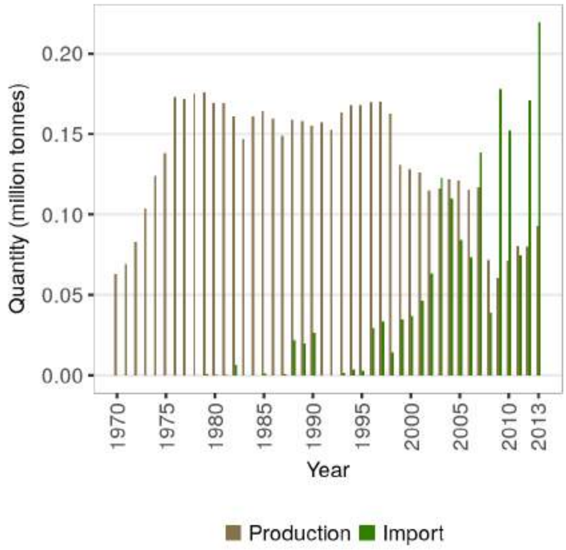
Source: FAOSTAT data.

Figure 5.12: Production of lentil by district, Bangladesh, 2014–15



Source: Data from Bangladesh Bureau of Statistics.

Figure 5.13: Production and imports of lentil in Bangladesh, 1970 to 2013



Source: FAOSTAT data, updated using national statistics.

local germplasm was collected, evaluated and cross-bred by BARI with germplasm lines from ICARDA to develop short-duration varieties of lentil with stable yields and disease resistance (Sarker *et al.*, 2004). In all, 17 improved varieties of lentil have been introduced through this collaboration. The rise in lentil yields has resulted in a sharp increase in area sown with lentil. In 2015, over 300,000 hectares of land in Bangladesh were under lentil cultivation, and the total production of lentil in the country went up to 139,000 tonnes.

In order to meet the large consumption demand for lentil within its borders, Bangladesh has become increasingly dependent on imports from Australia, Canada and Nepal (Figure 5.13). In 2014–15, the country imported about 181,000 tonnes of lentil (Bangladesh Bureau of Statistics, 2016).

Costs of Production and Returns from Lentil Cultivation

Table 5.7 presents summary data on the average cost of production and returns from cultivation of red lentil for India, Bangladesh, Australia and Saskatchewan (Canada). For the sake of comparability across countries, all costs were converted using producer prices to equivalent kilograms of lentil. The gross margins are

Table 5.6: Average annual production, yield and area of lentil in Bangladesh, 1980 to 2015

Triennium ending	Area (thousand hectares)	Yield (kilograms per hectare)	Production (thousand tonnes)
1980	292	591	172
1990	214	737	157
2000	180	781	141
2010	182	372	68
2015	306	450	139

Source: FAOSTAT data, updated using national statistics.

Table 5.7: Gross value of output, costs and gross margin for lentil cultivation in India, Bangladesh, Australia and Canada (equivalent kilograms of lentil)

Output, costs and gross margin	India* (2013–14)	Bangladesh (2011)	Australia (2015)	Saskatchewan, Canada (2016)
Gross value of output (USD per hectare)	512	594	586	1269
Yield (kilograms per hectare)	721	947	1200	1230
Producer price (USD per kilogram)	0.68	0.63	0.49	1.03
Variable costs				
Seed	53	91	80	81
Fertilizers and manure	22	80	59	23
Plant protection chemicals and inoculants	3	51	199	98
Irrigation	19	0		
Machinery and draught animals	104	190	71	55
Hired labour	67	0		31
Family labour	86	0		
Total labour	152	301		31
Interest on working capital	8	7		9
Insurance		0	14	33
Levies		0	22	
Miscellaneous	0.45	0		7
Total variable costs	363	721	445	339
Gross margin at farm gate				
Gross margin	387	226	755	891
Gross margin (USD per hectare)	264	142	369	919

*Gross value of output includes value of crop byproducts.
Source: Estimates are from CACP (2015); Government of Saskatchewan (2016); Government of South Australia (2015); and Rahman *et al.* (2013).

presented both in terms of equivalent kilograms of lentil and USA dollars.

These data show that returns from lentil cultivation are much higher in Saskatchewan (Canada) and Australia, where lentil is grown on large, capital-intensive farms, than in India and Bangladesh, where it is grown on small peasant holdings. In Saskatchewan, the yield of lentil is about 1.2 tonnes per hectare. The variable cost of production is equivalent to 339 kilograms per hectare of lentil, leaving a gross margin equivalent to 891 kilograms of lentil (USD 919) per hectare. In contrast, in Bangladesh, data for which are available only for 2011, returns from lentil production were equivalent to 226 kilograms of lentil (USD 142) per hectare. In India, in 2013–14, the gross margin was equivalent to 387 kilograms of lentil (USD 264) per hectare.

A striking difference between the structure of costs on peasant farms in India and Bangladesh, on the one hand, and large farms in Australia and Canada, on the other, is that while a substantial part of the total value of output of peasant farms goes towards expenses towards labour, animals and machinery, on large farms in Australia and Canada, the highest share in cost of production is of plant protection chemicals and inoculants.

Tasks like weeding are done manually on peasant farms, while these are dealt with chemically on large farms. Zero or minimum-till cultivation has been widely adopted on large-scale pulse farms in Canada and Australia (Carlyle, 2004; Llewellyn and D'Emden, 2010). This form of cultivation requires specialized seeding equipment and herbicides to deal with weeds, but it reduces the fuel costs. On peasant farms in India and Bangladesh, however, adoption of no-till or minimum-till cultivation is negligible because of the non-availability of appropriate technology to farmers and the inability of peasants to make the required capital investment.

Low per hectare gross margins doubly disadvantage smallholder producers in countries like India and Bangladesh. Not only do farms in Canada and Australia obtain much higher per hectare returns, given the large size of the farms, but these also translate into high per farm and per worker incomes. On a 1,000-hectare farm in Saskatchewan, the total annual gross margin of lentil cultivation in 2016 is expected to be USD 0.6 million. On the other hand, with most lentil producers in India and Bangladesh having less than 1 hectare of land, the total income from lentil production is equivalent to just a few hundred USA dollars.

Conclusions

The transformation of lentil production globally over the last four decades is characterized by the rise of large-scale, export-oriented production in the developed countries. About 46 percent of global lentil production is currently traded internationally. With large farms and high yields, Canada and, more recently, Australia have emerged as dominant players in the export market for lentil, and have edged out traditional exporting countries like Turkey.

There are two main types of lentil: red, microsperma varieties, which are consumed primarily in Asia in dehulled and split form; and green, macrosperma varieties, which are consumed primarily in West Asia, North Africa and Europe as whole grain. With growing concentration of lentil demand in South Asia, global production of lentil has increasingly shifted to red lentil.

This transformation of lentil production – both in terms of expansion to countries that did not produce lentil earlier and in terms of the composition of production in response to changing demand – has been possible because of systematic and painstaking work to build *ex-situ* collections of lentil germplasm, their evaluation and breeding. Breeding research in all the major lentil-producing countries has been based on collaboration between ICARDA and national agricultural research institutions. Public agricultural research institutions in the lentil-producing countries have been responsible for the evaluation and release of identified cultivars. Even in developed countries like Canada and Australia, initiatives by local governments were crucial in getting lentil production off the ground, and it was only in later years that levies from lentil producers became an important source of finance for research.

Having achieved considerable success in developing disease-resistant cultivars, the focus of research has shifted, in recent years, to mechanical harvestability and nutritional enrichment of lentil. The introduction of biofortified lentil in Bangladesh, Nepal and India is a huge step forward in the battle against widespread hidden hunger in the South Asian region.

It is important to point out, however, that despite the development of improved varieties for most lentil-growing regions of the world, large yield gaps still remain in countries where lentil production takes place on small peasant holdings. The average yields of lentil are only 722 kilograms per hectare in India and 420 kilograms per hectare in Bangladesh. These yields can be increased significantly with wider adoption of improved cultivars and better agronomic practices. Strengthening the systems of agricultural extension is crucial for achieving these results.

With increasing trade in lentil, certification issues have become important. Over much of the 1990s, Australian vetch, with known toxicity, was imported to South Asia and mixed with red lentil. A significant quantity of green lentil continues to be imported into South Asia for mixing with pigeonpea in dehulled and split form. More robust systems of certification are crucial to prevent such adulteration.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PIGEONPEA: SMALLHOLDER PRODUCTION

Jesim Pais and Vaishali Bansal

Introduction

Pigeonpea (*Cajanus cajan (L.) Millspaugh*), also known as red gram, is a rainfed food crop cultivated in the tropical and sub-tropical regions of the world. Pigeonpea seeds are a rich source of proteins, carbohydrates, and certain essential vitamins and minerals like calcium, phosphorous, potassium and iron. While dry pigeonpea seeds are mainly consumed in split form, green or tender pigeonpea is also widely eaten as a vegetable.

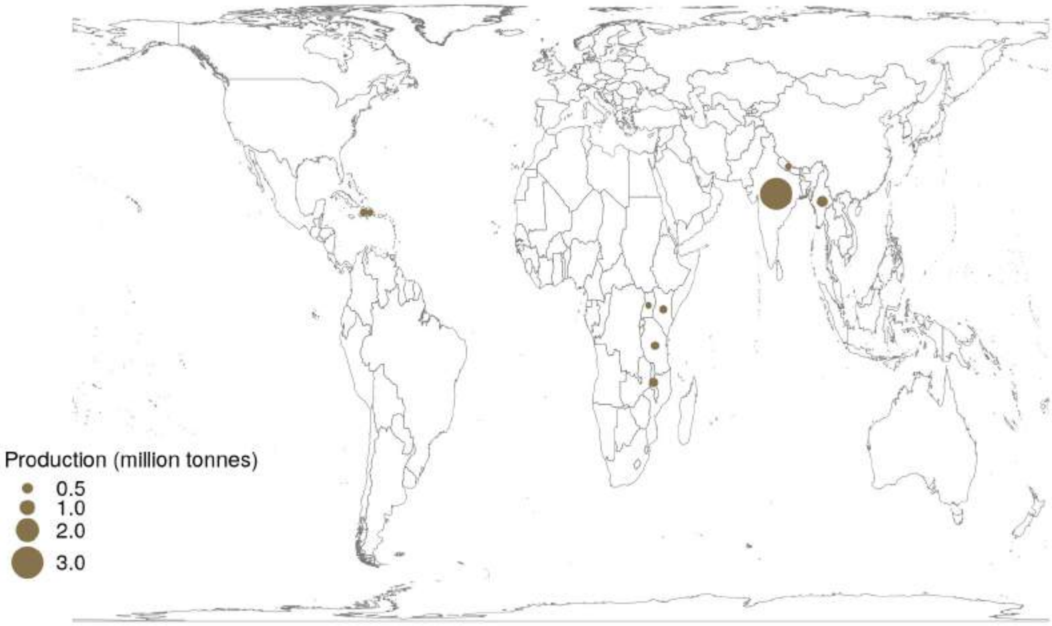
In the triennium ending 2014, global production of pigeonpea stood at 4.4 million tonnes. This constituted about 5.8 percent of total pulse production across the world. Over the last four decades, the rate of growth of production of pigeonpea has been slow, since it has been driven almost entirely by expansion of area under cultivation with yields remaining stagnant at about 7 quintals per hectare globally.

Production of pigeonpea globally is confined to developing countries in Asia, southeast Africa and the Caribbean (Figure 6.1). India and Myanmar in Asia dominate the global production of pigeonpea, together contributing about 80 percent. In 2012–14, India alone produced about 67 percent of the world's pigeonpea. After India and Myanmar, the countries that record substantial production of pigeonpea are Malawi (6.3 percent), Tanzania (5.3 percent) and Kenya (4.6 percent).

Although India leads in pigeonpea production by a wide margin, crop yields here are low as compared to other major pigeonpea-producing countries. In 2012–14, the per hectare yield of pigeonpea was 652 kilograms in India, 1,268 kilograms in Malawi and 921 kilograms in Myanmar (Table 6.1). Substantial yield gaps also exist among the top pigeonpea-producing countries in East Africa.

Myanmar, the second largest producer of pigeonpea in the world, has seen a substantial rise in production over the last three decades: from negligible production figures in the 1990s to 0.6 million tonnes in 2012–14. This growth was due to not only an expansion in the area sown with

Figure 6.1: Production of pigeonpea across different countries, 2012–14



Source: FAOSTAT data, updated using national statistics.

Table 6.1: Average production, yield and area harvested of pigeonpea, major producing countries, 2012–14

Country	Production (million tonnes)	Yield (kilograms per hectare)	Area harvested (thousand hectares)	Share in world production (percent)
India	3.0	652	4584	67.4
Myanmar	0.6	921	616	12.8
Malawi	0.3	1268	217	6.2
United Republic of Tanzania	0.2	855	274	5.3
Kenya	0.2	749	270	4.6
Haiti	0.1	803	109	2
Dominican Republic	0.0	1097	24	0.6
Nepal	0.0	905	17	0.4
World	4.4	718	6170	100

Source: FAOSTAT data, updated using national statistics.

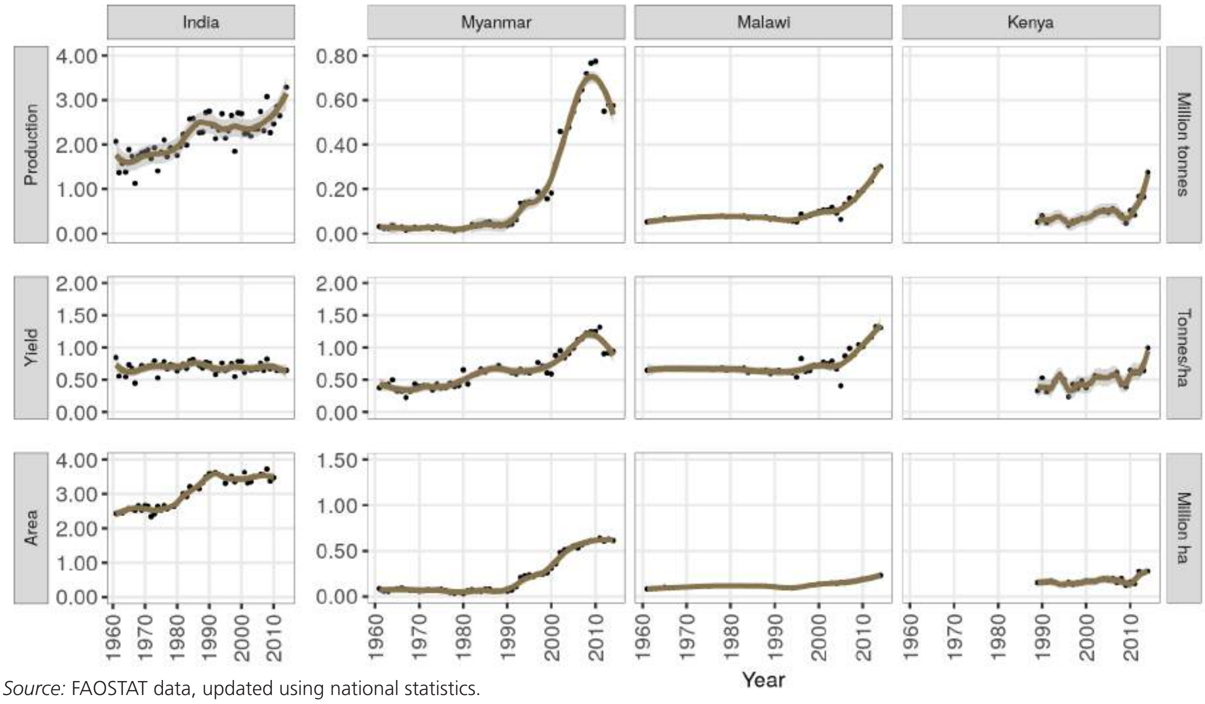
pigeonpea, but also a significant improvement in yields, particularly during the 2000s (Figure 6.2).

Cropping Systems

Pigeonpea has a high level of drought resistance and is mainly grown as an unirrigated, dryland crop. It can be grown on a variety of soils, and in conditions of both low (5–10°C) and high (up to 40°C) temperatures (Ali and Kumar, 2005; Sardana, Sharma and Sheoran, 2010).

The versatility of pigeonpea has led to it being part of a range of cropping systems. It is grown as a sole field crop, as an intercrop, as a homestead garden crop, as a hedge crop around homesteads, as a field boundary crop and as a windbreaker in fields (International Crops Research Institute for

Figure 6.2: Production, yield and area harvested of pigeonpea, major producing countries,1961 to 2014



Source: FAOSTAT data, updated using national statistics.

the Semi-Arid Tropics, 1986; Mula and Saxena, 2010; Snapp *et al.*, 2003). Pigeonpea is commonly intercropped with other short-duration crops like sorghum, maize, millet, cotton, groundnut, and even other pulses like mung bean and urd bean (Srivastava and Singh, 2001). When sown with another crop of shorter duration, the other crop can be planted with a density almost as high as a sole crop, and harvested before the pigeonpea plants grow very big (Mula and Saxena, 2010). Pigeonpea plants rapidly grow to their full size with a canopy once the other short-duration crop is harvested. Intercropping in such combinations has an incremental effect on the output and returns of pigeonpea, but no adverse impact on the output of the other crop. Pigeonpea requires only minimal quantities of fertilizer and does not compete with other crops with which it is planted. Where it is grown for use as green pea, 'indeterminate' varieties that produce multiple flushes of pods are preferred. Intercropping and growing indeterminate varieties of pigeonpea are also means to diversify the risk over multiple crops and flowerings in the context of dryland agriculture. Pigeonpea not only helps in enriching the soil by fixing atmospheric nitrogen and carbon, but its deep tap root system also anchors the soil well, helping prevent soil erosion (Panwar and Srivastava, 2012).

An important feature that distinguishes pigeonpea production from production of all other major pulses of the world is that pigeonpea is almost entirely produced by smallholder cultivators. Large-scale production of pigeonpea is insignificant. Since it is primarily grown as an intercrop or a border crop, average yields of pigeonpea vary not just by factors like seed variety, agronomic practices and agro-ecological conditions, but also because of variations in the density of planting.

Pigeonpea is traditionally cultivated in most African countries as a homestead garden crop for green peas, meant for self-consumption.[1] In Africa, the demand for pigeonpea as a pulse is limited to populations of Asiatic origin that are

1 While production estimates of fresh green pigeonpea in several African countries are not readily available, it is estimated that between 10 and 65 percent of pigeonpea produced on small holdings across Africa are consumed by the farmers themselves or shared/sold within the village (Mula and Saxena, 2010; Odeny, 2007).

Table 6.2: Popular improved varieties of pigeonpea in eastern and southern Africa

Country	Variety	Year of release	Characteristics
Kenya	KARI Mbaazi2 (ICEAP 00040)	1995	Long duration; large, cream seed; *Fusarium* wilt-resistant
	Katumani 60/8 (Kat 60/8)	1998	
	Karai (ICEAP 00936)	2011	
	Peacock (ICEAP 00850)	2011	Medium duration
Malawi	Sauma (ICP 9145)	1987	Long duration; *Fusarium* wilt-resistant
	Kachangu(ICEAP 00040)	2000	Long duration; large seed; *Fusarium* wilt-resistant
	Mwaiwathualimi(ICEAP 00557)	2010	Medium duration
	Chitedze pigeonpea 1 (ICEAP 01514/15)	2011	Medium duration; high pod load
Mozambique	ICEAP 00040	2011	Long duration
	ICEAP 00020	2011	Long duration
Tanzania	Komboa (ICPL 87091)	1999	Short duration (110–120 days)
	Mali (ICEAP 00040)	2002	Long duration (180–270 days)
	Tumia (ICEAP 00068)	2003	Medium duration (140–180 days)
	Kiboko (ICEAP 00053)	2015	Long duration; erect plant type
	Karatu 1(ICEAP 00932)	2015	Long duration
	Ilonga 14-M1(ICEAP 00554)	2015	Medium duration
	Ilonga 14-M2 (ICEAP 00557)	2015	Medium duration
Uganda	Sepi I (Kat 60/8)	1999	Medium maturity
	Sepi II (ICPL 87091)	1999	Short duration; multiple cropping

Source: Kaoneka *et al.* (2016).

concentrated in some of the major commercial centres. Cultivation of pigeonpea as a field crop has emerged in countries like Mozambique, Tanzania, Uganda, Malawi and Kenya relatively recently, in response to an export demand from the Indian subcontinent (Odeny, 2007; Snapp *et al.*, 2003). Development of suitable short-duration varieties of pigeonpea was key to its transition from a homestead garden crop to a commercial field crop in these countries. This was made possible because of successful collaboration between national agricultural research centres, the International Center for Agricultural Research in the Dry Areas (ICARDA) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (Silim, King and Tuwafe, 1994).

Biotic and Abiotic Yield Constraints

Waterlogging, frost, drought during the grain-filling stage and salinity of soil are the main abiotic stresses in cultivation of pigeonpea (Ali and Kumar, 2005; Desai, Ardeshna and Intwala, 2000; Mula and Saxena, 2010). Unwanted vegetative growth may also take place in excessively humid conditions (Mula and Saxena, 2010). Problems like waterlogging can be taken care of by employing appropriate agronomic practices such as raised-bed planting and surface drainage systems, and by using crop varieties of appropriate duration.

Fusarium wilt, a soil-borne fungal disease, is the most serious disease afflicting pigeonpea. It is a major constraint on production in India, and East African countries like Kenya, Malawi and Tanzania (Sharma and Ghosh, 2016). Wilt can result in complete yield loss if the disease appears on the field before the pods mature, and up to two-thirds crop loss if it occurs at the time of maturity of the plants (Soren *et al.*, 2012). Fungal build-up tends to happen on fields repeatedly cultivated with pigeonpea, which makes such lands susceptible to the disease.

Sterility mosaic disease (SMD) is a major viral disease affecting pigeonpea cultivation that is reported from India, Bangladesh, Nepal, Sri Lanka and Myanmar (Sharma and Ghosh, 2016). In India alone, SMD is estimated to cause an annual crop loss valued at USD 300 million (Patil and Kumar, 2015). *Phytophthora* blight, deep root rot and *Alternaria* blight are some of the other diseases of pigeonpea (Sharma and Ghosh, 2016).

Recently, considerable advance has been made in identifying high-yielding pigeonpea varieties with strong resistance to *Fusarium* wilt and SMD (Sharma and Ghosh, 2016). However, different pathogens cause wilt and SMD in different locations, making it difficult to provide a broadbased improved cultivar that is resistant to these biotic stresses (Patil and Kumar, 2015).

Apart from these diseases, there are over a hundred species of insects that cause damage to pigeonpea yields (Sharma, 2016). Pests such as pod borers (*Helicoverpa armigera*, *Maruca vitrata*), pod fly (*Melanagromyza obtusa*) and plume moth (*Exelastis atomosa*) pose major threats to pigeonpea cultivation.

Development of Pigeonpea Varieties and Hybrids

Globally, breeding of pigeonpea is led by ICRISAT. ICRISAT's germplasm repository has 13,771 accessions of pigeonpea germplasm and its wild relatives from 74 countries. In India, research on pigeonpea is done through the All India Coordinated Research Project on Pigeonpea, started by the Indian Council of Agricultural Research (ICAR) in 1996.

Pigeonpea breeding research has focused on developing short-duration, disease-resistant varieties. Varieties have also been developed for different agroclimatic conditions, crop seasons and durations, and for sole cropping and intercropping (Singh, Bohra and Singh, 2016). Pigeonpea cultivars are now available for a wide range of maturity durations (90 to 300 days). ICRISAT has identified eleven such maturity groups based on days of flowering and maturity (Kumar *et al.*, 2016a). The development of short-duration varieties has made it possible to include pigeonpea in crop cycles with two crops in a year – for example, with wheat (Kumar *et al.*, 2016a). In India, UPAS120, Asha, Maruthi and TJT 501 are some of the most widely used pigeonpea varieties. In Myanmar, HPA-1, BR-172, ICPL-87, ICPL 93003, ICPL 87119 and ICPL 96061 varieties have been released through collaboration with ICRISAT. Various improved varieties of different durations and other attributes have also been released in eastern and southern Africa by ICRISAT (Table 6.2).

Most pulse crops are self-pollinating in nature; therefore, it is not possible to produce hybrid seeds on a large scale. Pigeonpea is different from other pulse crops in this respect. While pigeonpea is mostly self-pollinated, a considerable degree of cross-pollination is done by honey bees. This has allowed the development of hybrids for commercial release. Wild relatives of cultivated species act as a rich source of genetic material required for breeding improved hybrids with desired traits such as high disease resistance, improved yields and better nutritive composition of the grain (Sharma and Upadhyaya, 2016). In 1991, ICRISAT and ICAR jointly developed the first hybrid, ICPH 8. Another hybrid, ICPH 2671, was released in 2008 in India. Recently, a third hybrid, ICPH 2740, with a yield advantage of 30–40 percent, was released. ICRISAT has also developed several hybrids for Myanmar by crossing male breeding lines with locally adapted germplasm lines. Several hybrids have also been tested in Myanmar and since 2008, ICPH 2740 has been released for production (Kyu, Shwe and Kumar, 2016). In collaboration with national research institutions, ICRISAT has released seven hybrids in Malawi, Kenya and Tanzania, five in Mozambique, two in Uganda and Zambia, and one each in Ethiopia and Sudan (Kaoneka *et al.*, 2016).

The pigeonpea genome has also been sequenced. This will help to speed up the ongoing breeding targeted at developing resistance against major pests like *Helicoverpa* (Kaoneka *et al.*, 2016).

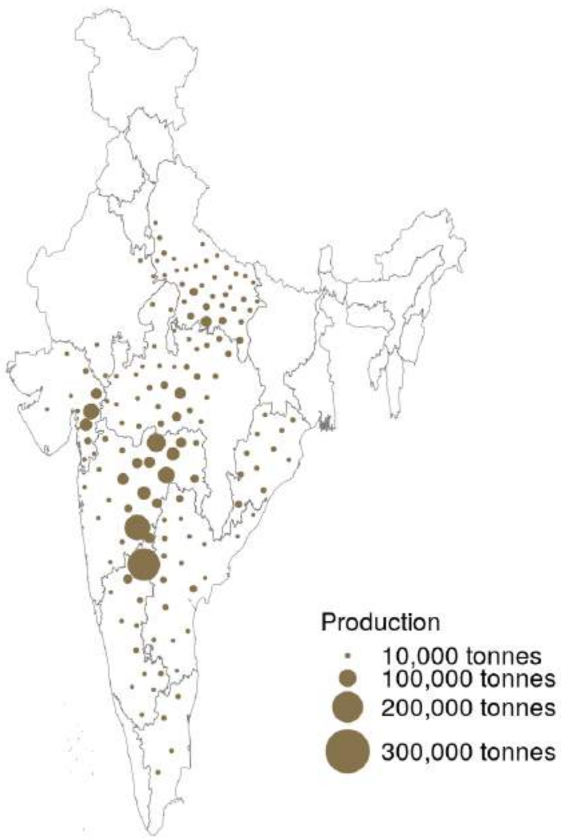
While considerable scientific work has been done by ICRISAT and ICAR to develop improved pigeonpea varieties and hybrids, and more is underway, the production and distribution of certified seeds among farmers remains a major bottleneck in most pigeonpea-producing countries. A substantial increase in extension is needed to ensure that yield advantages achieved through these scientific developments translate into on-farm productivity increases (Kaoneka *et al.*, 2016).

India: Production and Imports

Pigeonpea is the most widely consumed pulse in India. In 2011–12, average per capita consumption of pigeonpea in the country was about 8 grams per capita per day (NSSO, 2014). In terms of production, pigeonpea ranks second after chickpea. In 2011–13, about 16 percent of the total area under cultivation of pulses in India was under pigeonpea. Production of pigeonpea is concentrated in peninsular India, where it is grown throughout the year (Figure 6.3). In northern India, pigeonpea is mainly a *kharif* (rainy) season crop (Sardana, Sharma and Sheoran, 2010).

Table 6.3 shows that pigeonpea production in India has grown at an annual growth rate of barely 1 percent since the 1970s, primarily due to stagnant yields. In the period 1970 to 2013, there have been three phases in the growth of pigeonpea production in India (see Figure 6.2). The area under pigeonpea cultivation grew by about 1.8 percent per annum in the 1970s and 1980s. The second phase, from 1990 to 2005, saw a stagnation of yields and a decline in the area under pigeonpea. This phase, which coincided with the fifteen years since the onset of economic reforms, was a period of widespread agrarian stagnation in India (Ramachandran and Rawal, 2009). Dryland agriculture of pulses suffered the most in this phase. In the third phase, the period after 2005, due to an increase in public expenditure and an expansion in the provision of rural credit, there was a partial recovery of agricultural growth in India (Sen, 2016). There was a revival of area-led growth in the case of pigeonpea as well in this phase.

Figure 6.3: Production of pigeonpea by district, India, 2011



Source: Based on ICRISAT (2015) and Surjit (2016).

Table 6.3: Annual rate of growth of area sown, yield and production of pigeonpea, India, 1970 to 2013

Period	Area	Yield	Production
1970–1990	1.79	0.47	2.26
1991–2005	–0.22	0.16	–0.06
2005–2013	3.0	–0.12	1.8
1970–2013	1.07	–0.11	0.95

Source: Data from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

Given the slow growth rate of production, there is a large and growing deficit between domestic demand and supply of pigeonpea in India. Dhal (2014) estimated this gap to be about 0.5 million tonnes in 2012. India meets this deficit by importing pigeonpea from Myanmar, and East African countries like Tanzania, Mozambique and Malawi. India today is the world's largest importer of pigeonpea, with estimated imports in 2016 worth USD 457.05 million (Molier, 2016).

Major Exporters of Pigeonpea

Myanmar

Pigeonpea is an important pulse crop in Myanmar, accounting for about 10 percent of all pulses grown in the country. Cultivation of pigeonpea was introduced in Myanmar by Indian immigrants during the colonial period. However, widespread cultivation of the pulse is a relatively recent phenomenon.

Production of pigeonpea in Myanmar increased fourteen-fold between the triennium ending 1991 and triennium ending 2014. While this was primarily because of a significant expansion in the area sown with pigeonpea, from about 63,000 hectares in 1991 to 616,000 hectares in 2014, there was also an increase in yields in the same period, from about 645 kilograms per hectare to 921 kilograms per hectare (Figure 6.2).

Pigeonpea is a preferred crop among small farmers in the dry and semi-arid regions of Myanmar due to its drought resistance. It is cultivated mainly in the central dry zone of the country, in the divisions of Sagaing, Mandalay and Magway. Pigeonpea is also cultivated in hilly zones across the country, where its resistance to drought and requirement of minimal inputs make it a viable crop (Myint, 2012).

In Myanmar, pigeonpea is typically sown in the months of May–June and harvested in December–January. Cultivation of the pulse crop is dominated by traditional long-duration (>200 days) varieties, although a number of shorter and medium-duration varieties with higher yields have been introduced. Pigeonpea hybrids have also been successfully introduced since 2010–11 (Kyu, Shwe and Kumar, 2016). Traditional long-duration pigeonpea varieties are intercropped with cotton, groundnut, sesame, mung bean and sunflower in the central dry regions of Myanmar (Kyu *et al.*, 2011). Pigeonpea is also occasionally intercropped with soybean and cowpea (Mula and Saxena, 2010). The yield per hectare in Myanmar is about 921 kilograms, which is among the highest in pigeonpea-growing countries across the world. This high yield has been achieved partly due to the introduction of short-duration varieties and hybrids.

Domestic demand for pigeonpea in Myanmar is negligible and most of the production is for exports. Pigeonpea is consumed in the country only by persons of Indian origin, who account for about 2 percent of the population. According to USDA Global Agricultural Information Network (GAIN) reports, the largest share of exports from Myanmar, ranging between 84 and 90 percent in recent years, goes to India.[2] Other important trading partners are Singapore and China.

Both in terms of quantity and value, Myanmar is the largest exporter of pigeonpea to India (Tables 6.4 and 6.5). In terms of quantity of imports, 47.1 percent of Indian imports of pigeonpea in 2014–15 and 2015–16 originated from Myanmar. The central and eastern African countries of Mozambique, Tanzania, Malawi and Kenya are Myanmar's main trading competitors for pigeonpea in the Indian market. Myanmar has an advantageous access to the pigeonpea market in India because of it's geographical proximity to India, and because the lemon tur variety of pigeonpea produced in Myanmar is favoured in the Indian market over the varieties produced in the African countries. As seen in Tables 6.4 and 6.5, because of these advantages, the average unit price of pigeonpea exports from Myanmar to India is marginally lower than the pigeonpea exported from Africa even when the pigeonpea from Myanmar is of a better quality.

Malawi

Malawi is the largest producer and exporter of dry pigeonpea in Africa. In the triennium ending 2014, the country's annual production of pigeonpea was 275,000 tonnes. Malawi has

2 http://www.aicrpmullarp.res.in/

a well-developed processing industry with capacity to produce and export dehulled split peas. In terms of total production, pigeonpea is the second most important pulse crop in Malawi after common bean (Simtowe *et al.*, 2009).

Production of pigeonpea in Malawi is marked by high average yields: the average yield in 2012–14, 1,268 kilograms per hectare, was the highest among all major pigeonpea-producing countries of the world. Yield increases in the country since 1985–86 are attributed to the availability of improved seeds (Simtowe *et al.*, 2009).

Cultivation of pigeonpea in Malawi is concentrated in relatively dry locations in the south, such as Blantyre, Machinga and Shire Valley. Marketing and processing facilities are also well developed in these areas. While Malawi produces dry pigeonpea mainly for export, there is some domestic demand for it in the southern region (Mula and Saxena, 2010).

Most pigeonpea producers in the country are smallholder farmers who usually intercrop pigeonpea with maize (Mula and Saxena, 2010). Occasionally, pigeonpea is also intercropped with groundnut (Simtowe *et al.*, 2009).

Tanzania

Pigeonpea is an important pulse crop in the dry and arid regions of Tanzania. A large proportion of the produce is reserved for export markets since the domestic demand is limited. The crop is grown for dry grain in the interior regions of the country and for green peas along the coast (Mula and Saxena, 2010). Trade liberalization has resulted in an increase in the area, production and exports of pigeonpea in Tanzania. Breeding research on pigeonpea started at the Agricultural Research Institute (ARI), Ilonga, in the 1960s. After the 1990s several new wilt-resistant and short-duration varieties were introduced, leading to accelerated production. The area sown with pigeonpea also doubled over the last decade, from 129,000 hectares in the triennium ending 2001 to 274,000 hectares in the triennium ending 2014.

In Tanzania, pigeonpea is generally intercropped with maize. A survey of four districts in northern Tanzania conducted by Amare, Asfaw and Shiferaw (2011) found that 88 percent of farmers intercropped maize with pigeonpea. The survey also showed that 43 percent of producers used improved varieties of maize, 34 percent used improved varieties of pigeonpea, and 19 percent used improved varieties of both maize and pigeonpea; and that adoption of improved varieties increased with availability of credit and extension services (*ibid.*). Another study, Shiferaw, Kebede and You (2008), found that adoption of improved pigeonpea varieties reduced disease-induced yield losses from 50 percent to just 5 percent, and increased household incomes by up to 80 percent. It identified lack of information and lack of adequate supply of new cultivars as the major reasons for farmers not adopting disease-resistant varieties. As seed requirements and the cost of procuring seeds for pigeonpea were small, lack of availability of credit was not a major limiting factor in making planting decisions for new varieties.

Smallholder producers of pigeonpea in Tanzania market a substantial portion of their annual produce, and export a large part of it to India. According to one estimate, between 10 to 20 percent of pigeonpea produced in the country is consumed domestically, and the rest is exported (Simtowe *et al.*, 2009). In 2015–16, Tanzania exported about 80,000 tonnes of pigeonpea as whole grain to India.

Kenya

Pigeonpea is important as a secondary crop in local farming systems in Kenya. It is mainly intercropped with maize, which is the staple cereal crop, and sorghum. Other crops that pigeonpea is intercropped with include beans, cowpea, cassava, mung bean and dolichos bean. Pigeonpea is also grown as a 'trap' crop with crops like passion fruit, for example, to distract insects away from the fruit. Due to its high export demand it is also grown as a sole crop in some regions such as the coastal strip and in Ukambani (Snapp *et al.*, 2003).

Pigeonpea is grown in Kenya as both a vegetable crop and an export crop. In the Thavu region it is the main cash crop, while in the Karaba region it is second to mung bean. In the dry plains, varieties of pigeonpea that take nearly a year to

Table 6.4: Imports of pigeonpea in India, 2014–15

Country of origin	Total quantity (tonnes)	Total value (million INR)	Average unit value (INR per kg)	Share in quantity (percent)	Share in value (percent)
Myanmar	290820	13819.4	47.5	47.1	48.0
Mozambique	157010	7118.9	45.3	25.4	24.7
Tanzania	101944	4725.7	46.4	16.5	16.4
Malawi	45955	2090.3	45.5	7.4	7.3
Sudan	16741	768.9	45.9	2.7	2.7
Kenya	4346	206.8	47.6	0.7	0.7
Uganda	1202	51.9	43.2	0.2	0.2
Total	618018	28781.9	46.6	100.0	100.0
Africa	327198	14962.5	45.7	52.9	52.0

Source: Estimates from shipment data.

Table 6.5: Imports of pigeonpea in India, 2015–16

Country of origin	Total quantity (tonnes)	Total value (million INR)	Average unit value (INR per kg)	Share in quantity (percent)	Share in value (percent)
Myanmar	214239	15331.5	71.6	47.1	46.5
Tanzania	80299	6078.0	75.7	17.6	18.4
Mozambique	69675	5237.7	75.2	15.3	15.9
Malawi	58290	3913.3	67.1	12.8	11.9
Sudan	16773	1202.9	71.7	3.7	3.7
Kenya	9551	702.8	73.6	2.1	2.1
Uganda	6367	477.6	75.0	1.4	1.4
Ethiopia	72	4.7	65.1	0.0	0.0
Benin	37	2.4	66.1	0.0	0.0
Total	455302	32950.8	72.4	100.0	100.0
Africa	241064	17619.3	73.1	52.9	53.5

Source: Estimates from shipment data.

mature are cultivated. These are planted during short rains in November, and harvested in July or August, depending on rainfall and maturity of the yield. Ratoon cropping is also practised in some parts of Kenya. While maize is the main crop, in the event of failure of rains, pigeonpea yields become crucial for livelihood and food security.

Kenya was the sixth largest exporter of pigeonpea to India in 2014–15 and 2015–16 (Tables 6.4 and 6.5). Kenya exported about 9.6 thousand tonnes of pigeonpea to India in 2015–16. The total land under pigeonpea in the country increased from 95,272 hectares in 1985 to 200,000 hectares in 2005 (Mula and

Saxena, 2010). While small farmers consume green pigeonpea grown on their own land, in urban areas pigeonpea is consumed as dry seeds by low-income consumers. In urban Kenya there is a substantial market for green pigeonpea, for consumption by high-income consumers (Simtowe *et al.*, 2009).

Mozambique

Although pigeonpea is considered a minor crop in Mozambique, it is planted widely across the country in kitchen gardens. It is commonly grown as a boundary crop in fields of maize, cassava and cowpea. It is often grown for a period of two years or more, with pruning undertaken before the rains.

Traditionally, pigeonpea is cultivated using farm-kept traditional seeds under rainfed conditions, with negligible other inputs. Modern cultivation practices are followed only when seeds of improved varieties are obtained through extension services.

Agriculture in Mozambique is dominated by small holdings, which account for about 95 percent of the agricultural produce of the country. There are about 400 very large commercial farms that account for the remaining 5 percent of agricultural output. There is no evidence to suggest that pigeonpea is grown in these large commercial farms.

In terms of production quantities, pigeonpea ranks third after maize and cassava, and is an important export crop of Mozambique (Walker *et al.*, 2015). It is exported as whole grains to India directly as well as through Malawi (Mula and Saxena, 2010). With India being the sole importer of pigeonpea grown in Mozambique, neighbouring Tanzania is its main trading competitor. In 2014-15 and 2015-16, Mozambique was among the top exporters of pigeonpea to India (Tables 6.4 and 6.5). It accounted for 25.4 percent of pigeonpea imports by India in 2014–15 and about 15.3 percent in 2015–16.

Two key institutions have been identified as being responsible for the growth and expansion of pigeonpea cultivation and pigeonpea exports from Mozambique. First, the agricultural research institution of the country, Instituto de Investigação Agrária de Moçambique (IIAM), which, along with ICRISAT, is credited with releasing and promoting the cultivation of medium-duration and high-yielding varieties of pigeonpea that are resistant to *Fusarium* wilt (Simtowe *et al.*, 2009). The medium-duration varieties with their 'early' maturity allow the crop to escape terminal drought stress in years when dry-season rainfall is scanty. The second institution is the Export Trading Group (ETG), which has been responsible for a large share of pigeonpea exports from Mozambique (*ibid.*).

Other Producers

Pigeonpea is cultivated in small quantities in some countries in Latin America and the Caribbean, in Dominican Republic, Haiti, the Panamas and Puerto Rico. In most of these countries, it is consumed as green peas. Dominican Republic even exports canned green pigeonpea to the USA. Production of pigeonpea in these countries, however, has been on a decline in recent years, with no significant increase in area or yield.

Sudan, Ethiopia and China have a history of pigeonpea cultivation, and are considered to have substantial potential for expansion. In China, for instance, pigeonpea can be produced not just for domestic consumption as fresh or dry peas, but also for use as livestock fodder, as substrate for mushroom and lac production, for use of its leaves and roots in traditional medicine, and use of pigeonpea plantations for controlling soil erosion (Mula and Saxena, 2010).

Conclusions

Pigeonpea is a dryland crop, grown mainly in the tropical and sub-tropical regions of the world. Unlike other pulse crops, pigeonpea is almost entirely produced by small peasants. It is a versatile pulse crop that can be adapted to many different types of cropping systems. It is often intercropped with short-duration crops like sorghum, maize, millets, and pulses like mung bean and urd bean. Pigeonpea is mainly consumed in the Indian subcontinent. In Africa, it was traditionally grown as a homestead garden crop and field boundary crop for producing green peas for consumption.

Pigeonpea production in the world is confined to the developing countries of Asia, southeastern Africa and the Caribbean. India accounts for 67 percent of global production. Myanmar, where pigeonpea is produced for exporting to India and, to a smaller extent, other countries in South Asia, accounts for about 13 percent of global production.

Pigeonpea is an important legume in Indian food; in particular, it is the most commonly consumed pulse in southern parts of India. Pigeonpea production in India has grown at a rate of only about 1 percent per annum since the 1970s. The yields are low and stagnant. With a growing deficit between domestic demand and supply, India has become increasingly dependent on imports of pigeonpea. It sources its supplies from Myanmar, and the East African countries of Tanzania, Mozambique and Malawi. The large Indian demand for pigeonpea has created opportunities for expansion of pigeonpea cultivation in these countries.

Development of suitable short-duration varieties through successful collaboration of ICARDA and ICRISAT with national research institutions has been crucial for the expansion of commercial pigeonpea production in Myanmar, Mozambique, Tanzania, Uganda, Malawi and Kenya. Pigeonpea is also different from most other pulse crops in terms of a substantial degree of cross-pollination. This has been used to develop hybrids for commercial release and distribution to farmers. Breeding research in pigeonpea has focused on developing short-duration, disease-resistant varieties and hybrids.

Although improved varieties and hybrids have been developed for different agroclimatic conditions, crop seasons and cropping patterns, there is still a large gap between potential and actual yields. This points to the need for a substantial push of extension services, to take new seeds and agronomic practices to the smallholder producers who grow pigeonpea.

DRY PEA: PRODUCTION DRIVEN BY DEMAND FOR ANIMAL FEED

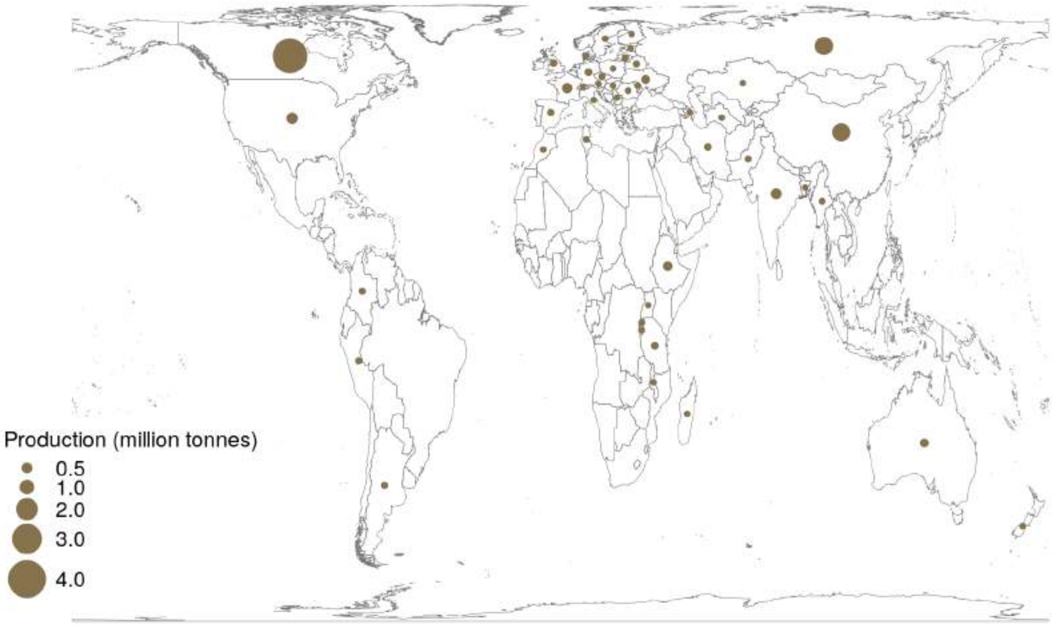
Prachi Bansal and Vaishali Bansal

This chapter deals with dry pea (*Pisum sativum*), a cool season legume produced for use as both food and animal feed (Figure 7.1). With a considerably higher content of amino acids, lysine and tryptophan than cereals, dry pea is rich in nutrients. It has 5 to 20 percent less of trypsin inhibitors than soybean, the legume most widely used as animal feed, making it possible for dry pea to be directly fed to livestock without going through the extrusion heating process (Miller *et al.*, 2005). Peas, in general, are rich in protein, complex carbohydrates and dietary fibres. They have many health benefits, including improved gastrointestinal function and a lower Glycemic Index which helps to manage type 2 diabetes (Dahl, Foster and Tyler, 2012b). Peas also have higher soil nitrogen fixation capacity than other pulse crops along with several other benefits in crop rotation.

There has been a very significant decline in global production of dry pea over the last two decades. In the triennium ending 1991 it accounted for 26 percent of total pulse production in the world, whereas by the triennium ending 2014, its share had fallen to just 14.5 percent. Between 1989–91 and 2012–14, the total area sown with dry pea fell from 8.7 million hectares to 6.9 million hectares. This global decline was the result of a shift away from use of dry pea to soybean, which is a cheaper source of plant protein, as animal feed in developed countries. In 1991, 63 percent of global dry pea production was used as animal feed; by 2011, this share had fallen to 34 percent.

Although there has been a significant decline in global production of dry pea, it must be noted that the overall global trend masks massive regional variations in trends. Canada is the largest producer of dry pea in the world with a share of 32 percent, followed by the Russian Federation (13 percent), China (13 percent), the United States of America (6 percent), India (5 percent) and France (5 percent) (Table 7.1). Canada, Russia, the USA, France and Australia are major exporters of dry pea (Table 7.2), while India, China, Bangladesh, Pakistan and Belgium are major importers (Table 7.3).

Figure 7.1: Production of dry pea across different countries, 2012–14



Source: FAOSTAT data.

Table 7.1: Average production, yield and area harvested of dry pea, major producing countries, 2012–14

Country	Production (million tonnes)	Yield (kilograms per hectare)	Area harvested (thousand hectares)	Share in world production (percent)
Canada	3.58	2519	1429	32.02
Russian Federation	1.50	1501	1008	13.45
China	1.50	1640	912	13.36
United States of America	0.66	2114	311	5.92
India	0.61	831	732	5.44
France	0.52	3977	132	4.69
Ethiopia	0.35	1381	254	3.13
Ukraine	0.33	1852	179	2.91
Australia	0.29	1298	226	2.61
Islamic Republic of Iran	0.19	408	466	1.70
World	11.19	1617	6919	100.00

Source: FAOSTAT data.

There are wide variations in yields of dry pea across countries. Among the major producing countries, yields vary from as low as 831 kilograms per hectare in India to as high as 3,977 kilograms per hectare in France (Table 7.1). These variations in turn reflect significant differences in production conditions, extent of adoption of improved varieties and adoption of modern

Table 7.2: Annual exports, share in world exports and ratio of exports to production of dry pea, major exporting countries, 2011–13

Country	Exports (thousand tonnes)	Share in world exports (percent)	Ratio of exports to production (percent)
Canada	2538	56	78
Russian Federation	463	10	28
United States of America	378	8	78
France	281	6	49
Australia	209	5	64
World	4519	100	41

Source: FAOSTAT data.

Table 7.3: Annual imports, share in world imports and ratio of imports to gross supply of dry pea, major importing countries, 2011–13

Country	Imports (thousand tonnes)	Share in world imports (percent)	Ratio of imports to gross supply (percent)
India	1532	36	72
China	832	20	37
Bangladesh	260	6	95
Pakistan	150	4	81
Belgium	120	3	113
World	4231	100	38

Source: FAOSTAT data.

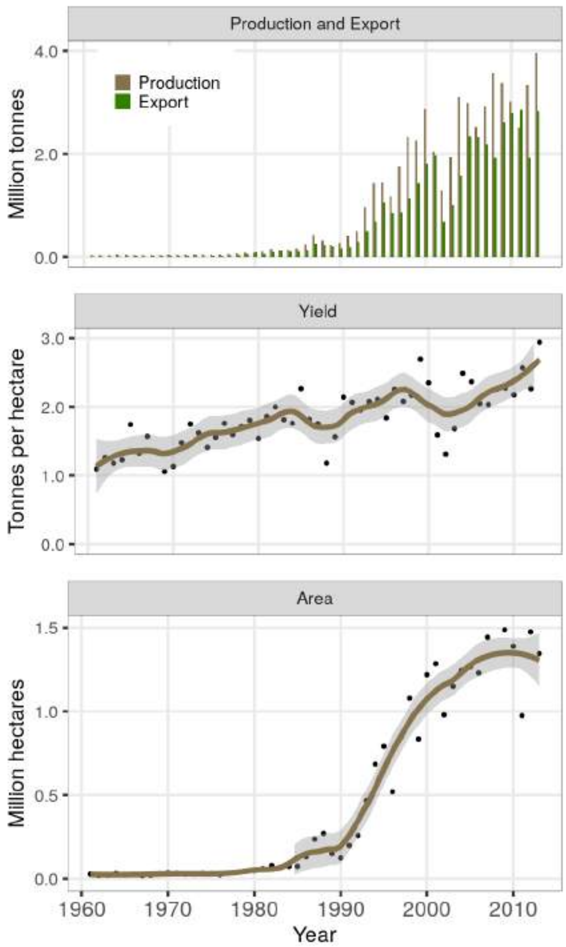
agronomic practices. In the absence of adoption of improved varieties and modern practices, dry pea production suffers from several biotic and abiotic stresses (Miller *et al.*, 2005). Like most other legumes, the crop competes poorly with weeds, and is highly susceptible to diseases like *Fusarium* wilt and powdery mildew. Radiant frost, particularly in the temperate regions of the world, is a major abiotic stress afflicting the pulse crop (Maqbool, Shafiq and Lake, 2010).

Canada: World Leader in Dry Pea Production

Canada is the largest producer of dry pea in the world, accounting for 32 percent of global production in 2012–14. Dry pea is the most important pulse crop of Canada. In the triennium ending 2014, dry pea constituted 61 percent of the total production of pulses and 53 percent of the total area sown with pulses in the country.

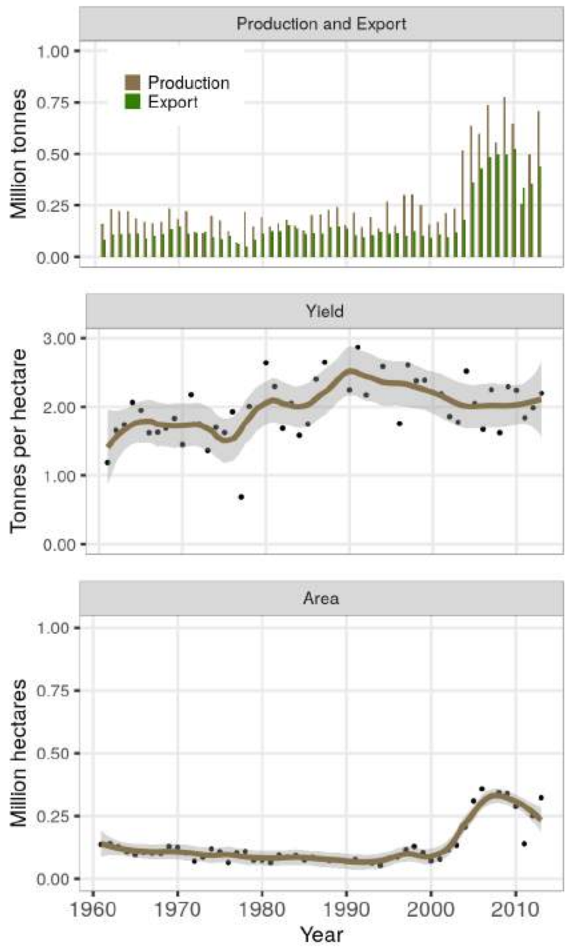
Until about the middle of the twentieth century, production of dry pea in Canada was concentrated in the eastern parts of the country. Over time, however, dry pea was displaced by cultivation of soybean in eastern Canada (Skrypetz, 2000). In the 1990s, cultivation of dry pea started to expand in western Canada, with Alberta and Saskatchewan becoming the largest producers, followed by Manitoba and British Columbia (Morgan, 2016). With the expansion of large-scale, export-oriented, no-till production in its western states, Canada emerged as the world's leading exporter of dry pea (Bekkering, 2014b).

Figure 7.2: Production, yield and area sown with dry pea, Canada, 1961 to 2013



Source: FAOSTAT data.

Figure 7.3: Production, yield and area sown with dry pea, USA, 1961 to 2013



Source: FAOSTAT data.

The increase in production in Canada from the early 1990s was the result of an expansion in the area sown with dry pea (Figure 7.2). Between 1990 and 2014, dry pea production in Canada grew at a rate of 8 percent per annum, from 0.26 million tonnes to 3.44 million tonnes. This was primarily due to an expansion of land under dry pea cultivation in this period, at a yearly rate of 7.3 percent.

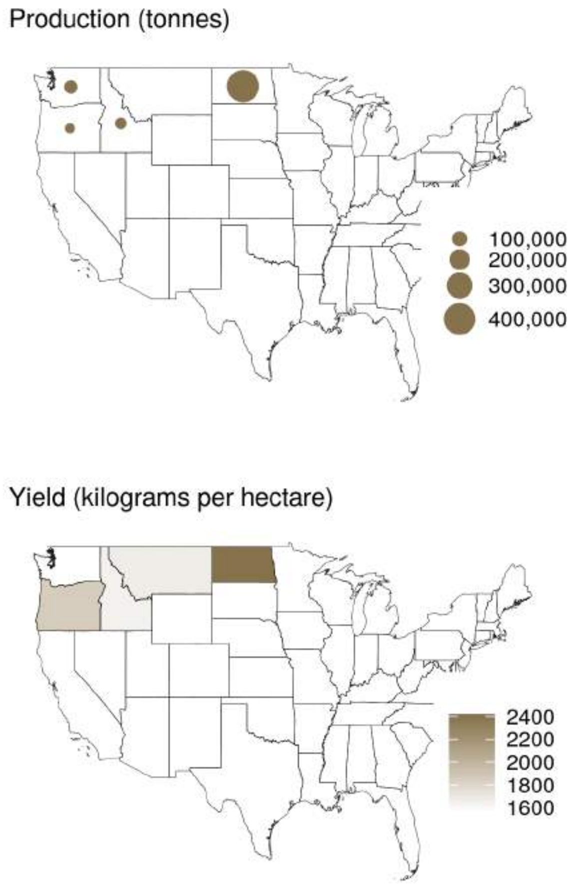
This massive expansion in the production of dry pea took place because of a high demand for animal-feed peas from the European countries, and peas for human consumption from the Indian subcontinent and China. Canada exported large quantities of dry pea to Europe in the 1990s for use as animal feed. However, with increasing availability of soybean as a cheaper substitute, the import demand from Europe declined after the mid-2000s. While there continues to be some domestic demand for dry pea as animal feed – an average of 55,000 tonnes a year were used as animal feed in Canada between 2001 and 2006 – India and China, where it is used for human consumption, have emerged as major importers of Canadian dry pea in recent years (Pulse Canada, 2007).

Exports of dry pea have grown considerably since the 1990s. Figure 7.2 shows that a very high share of production, between 75 to 80 percent, is exported.

The United States of America: Export-oriented Production

The United States of America, with large-scale no-till and high-yield production of dry pea, has emerged as another major exporting country. In the triennium ending 2014, the USA produced 0.66 million tonnes of dry pea with an average yield of 2,114 kilograms per hectare. In 2011–

Figure 7.4: Production and yield of dry pea by State, USA, 2013–15



Source: Data from USDA.

13, the last triennium for which trade data are available, the USA exported 78 percent of its total production. India and China are the major markets for dry pea grown in the US. There has been a sharp rise in dry pea production in the USA from 2000 due to rapid expansion of the area under dry pea cultivation: production expanded from 0.17 million tonnes in 2000 to 0.7 million tonnes in 2013 (Figure 7.3). Production of dry pea in the USA is concentrated in the states of Montana and North Dakota (Figure 7.4).

Europe: Decline of Production

In Europe, dry pea is mainly grown to meet the protein requirements of animal feed. Dry pea accounts fo r about 12 percent of total pulse production across Europe. Russia, France and Ukraine are the top producers of dry pea in Europe; of these countries Russia, with 1.5 million tonnes of annual production in 2012–14, is the second largest producer of dry pea in the world.

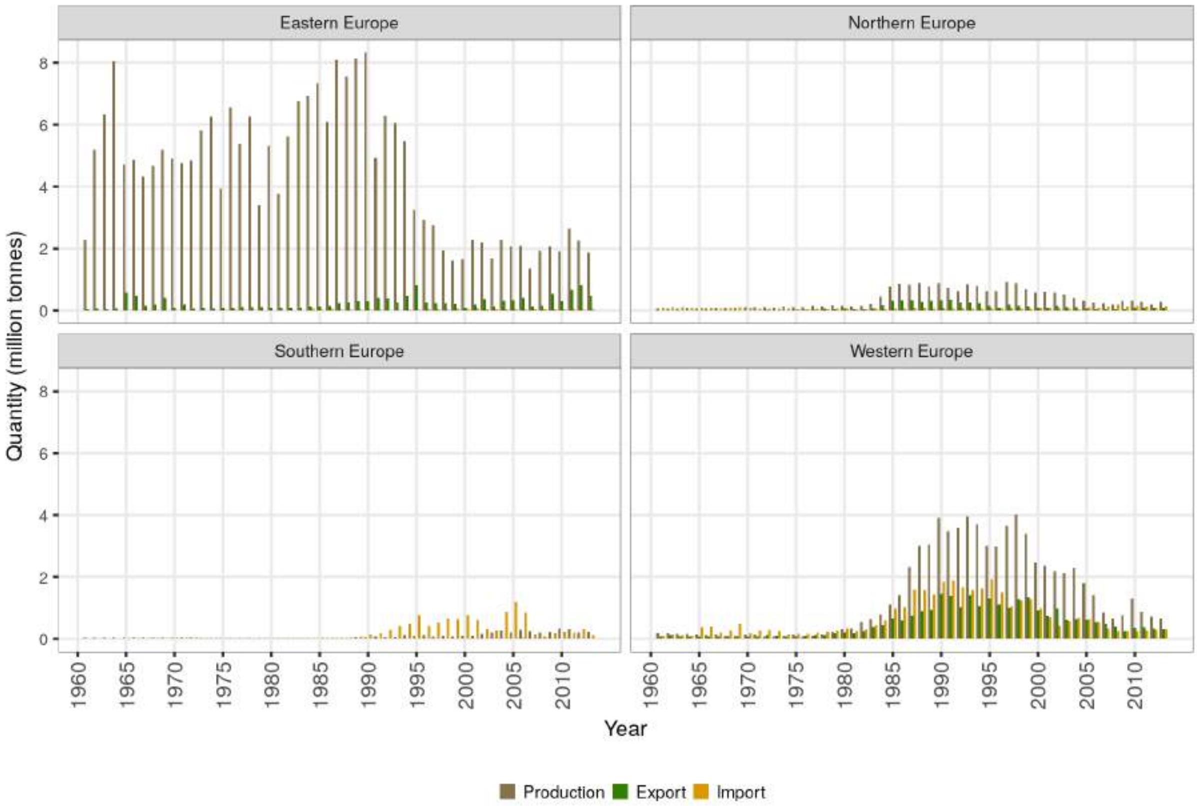
Production of dry pea in Europe was traditionally concentrated in Eastern Europe and in Western Europe (Figure 7.5). In both these regions, however, there has been a significant decline in production over the last two decades. In the early 1990s, dry pea accounted for about 24 percent of Europe's total pulse production; by 2012–14, this had fallen to about 13 percent. It is noteworthy, however, that while both Eastern and Western Europe suffered a decline in dry pea production, the reasons for the decline were somewhat different in the two regions.

Eastern Europe was the world leader in production of dry pea until the 1990s, with the Soviet Union accounting for about half of the global production. Within the Soviet Union, Russia and Ukraine were the largest producers of dry pea, but production in both declined after the dissolution of the USSR. Production of dry pea in the Russian Federation declined from 2.5 million tonnes in 1992–94 to 1.5 million tonnes in 2012–14; Ukraine's production fell from 2.7 million tonnes to only 0.3 million tonnes in the same period (Figure 7.5).

In the 1960s and 1970s, Western Europe depended on imports of soybean from the United States to fulfil the requirements of protein in livestock feed (Figure 7.6). When the USA suffered a shortfall in production, it imposed an embargo on exports of soybean to Europe. This led the European Economic Community (EEC) to take policy measures to reduce its dependence on imports of soybean. In 1978, a system of price support was introduced for the production of dry pea and other pulse crops for use as livestock feed. In 1982, price support was extended to the production of pulses for human consumption (Bues *et al.*, 2013). As a result, pea production in Western Europe multiplied six-fold, from 1 million tonnes in 1980 to 6.4 million tonnes in 1995, and France emerged as the leading producer of dry pea in Western Europe.

Europe started shifting from price support to area-based direct payments in 1992 under MacSharry Reform. Area-based payments were computed for each crop using a basic amount

Figure 7.5: Trends in production, exports and imports of dry pea in Northern, Southern, Eastern and Western Europe, 1961 to 2013 (million tonnes)

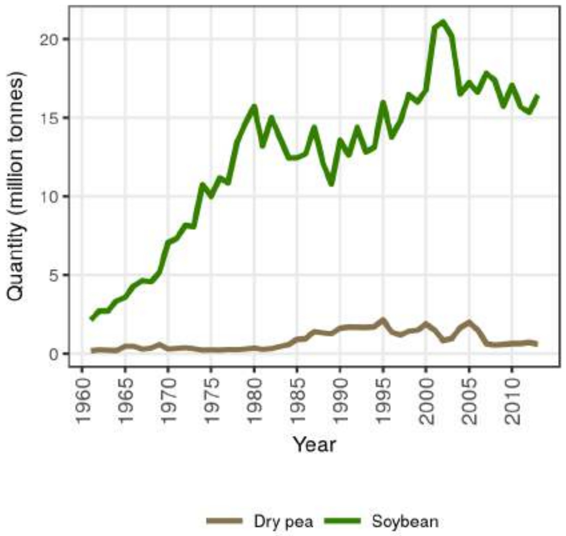


Source: FAOSTAT data.

(specified in European currency unit, ECU, per tonne) multiplied by regionally specific reference yield. During this phase of area-based payments (between 1992 and 2003), pulse crops received greater support (65 ECU per tonne) than soybean (16.5 ECU per tonne), which was categorized as an oilseed. Also, the Blair House Agreement of 1992, signed between the European Union (EU) and the USA as part of the Uruguay Round negotiations of WTO, imposed restrictions on the extent of area that could be brought under cultivation for support to soybean (Bues *et al.*, 2013). With limited support for soybean production, imports of soybean and dry pea to Europe increased significantly over the 1990s (Figure 7.6). Over the 1990s, Canada emerged as a large producer and exporter of dry pea. Although pulse crops were provided higher support than soybean in Europe, the production and area of dry pea in Western Europe stagnated due to competition from imported soybean and dry pea.

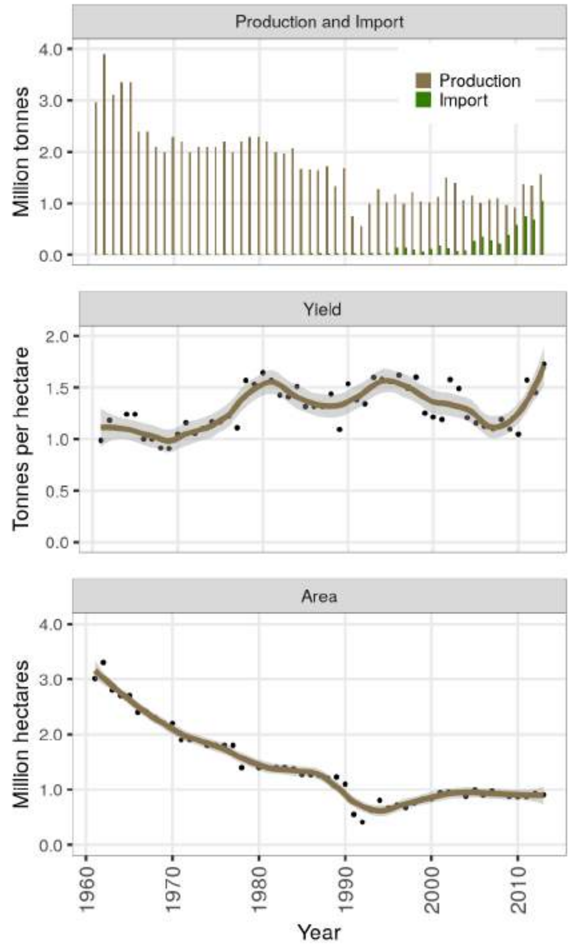
The introduction of decoupling – whereby support to farmers was made independent of what and how much they produced – in 2003 further reduced support to pulse crops in the EU. While countries gradually shifted to the Single Payment Scheme (SPS) over the years, three different forms of support were extended to legume crops. (i) A few East European countries used the Complementary National Direct Payments (CNDPs), a top-up over decoupled payments based on national budgetary resources, to support legume crops. (ii) Until 2012, a large number of EU countries provided a protein premium of €56 per hectare over and above the SPS payment. (iii) Until 2010, France and Spain continued with limited use of coupled (that is, crop- and production-linked) payment to extend support to legume crops. Bues *et al.* (2013) report that although twenty out of twenty-seven EU countries continued with a certain amount of support for pulse crops, the total value of support fell from €500 million in 2004 to just €70 million in 2005. Margins in the production of pulse

Figure 7.6: Import trends for dry pea and soybean, Europe, 1961 to 2013



Source: FAOSTAT data.

Figure 7.7: Production, yield and area sown with dry pea, China, 1961 to 2013



Source: FAOSTAT data.

crops are considerably lower than for competing crops like wheat, maize, rapeseed, potatoes and sugarbeet. With a reduction in crop-specific support, the area and production of dry pea and other pulse crops plummeted in the EU region. In 2008, Western Europe produced only 2.2 million tonnes of dry pea. There has been some revival of dry pea production in recent years on account of rising prices of soybean and increased costs of nitrogenous fertilizer, and a reduction in comparative disadvantage of pulse production because of an increase in the prices of pulses (Bues *et al.*, 2013).

China

China is the third largest producer of dry pea, with a share of about 13 percent in global production in 2012–14. However, China's production of dry pea has seen a sharp and steady fall since the 1960s: from 3.3 million tonnes annually in 1961–63 to about 1 million tonnes by 2008–10 (Figure 7.7). This fall was driven by a sharp reduction in the area under pea cultivation because of a shift towards cultivation of wheat and barley, which is more profitable.

The decline in production has led to China becoming a net importer of dry pea in recent years; it imported 0.83 million tonnes of dry pea in 2011–13. Yellow pea is increasingly used as a substitute for mung bean in vermicelli noodles (Serecon Inc, 2016). There has also been an increase in the demand for dry pea for production of starch. China mainly imports yellow pea from Canada and the US. After India, China is the second biggest importer of dry pea from Canada (Figure 7.7): in 2014 it imported 0.73 million tonnes of dry pea from Canada (Zarrouki, 2015) and in 2015 this rose to 0.81 million tonnes.[1]

Dry pea is used in China as animal feed as well as for human consumption. It is estimated that about 20 percent of dry pea used in China is as animal feed (particularly in aquaculture), about 15 percent for starch production and the rest for human consumption (GAIN, 2014;

1 http://www.statpub.com

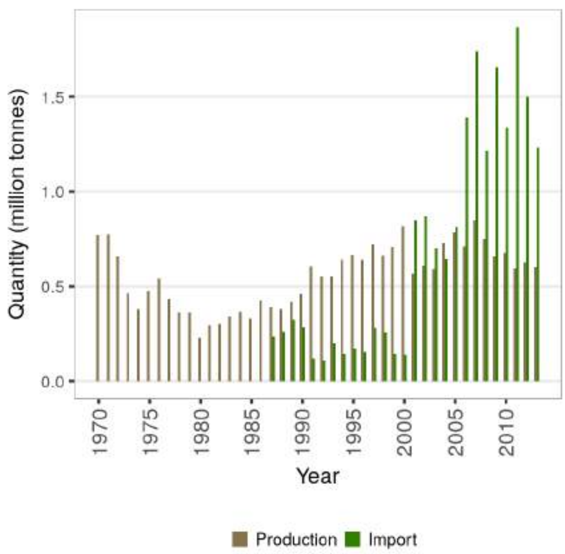
Zarrouki, 2015). Gansu, Ningxia, Qinghai, Sichuan, Yunnan, Guizhou, Chongqing, Jiangsu, Hubei, Shanxi, Hebei, Shandong, Inner Mongolia, Xinjiang, Liaoning and Guangdong are the major dry pea-producing provinces of the country (Li *et al.*, 2016). The southern provinces (Sichuan, Hunan, Hubei, Zhejiang, Guangdong, Guangxi, Fujian and Yunnan) use the common rotation system of cultivation, whereby pea is rotated in a three-year crop cycle with rice, barley and canola. On the southeastern coast of China (Jiangsu, Shanghai, Zhejiang, Anhui and Henan) pea is intercropped with maize, vegetables and cotton. Pea is a part of several different cropping systems in the northern parts of China. These include intercropping with maize, potato, canola and sunflower, and also rotating pea with other crops like wheat, barley and potato.

India

In terms of volume of production, dry pea is a relatively minor pulse crop in India and accounts for only about 3 percent of total pulse production in the country. It is, however, interesting to note that India is the biggest importer of dry pea in the world. As seen in Figure 7.8, Indian imports of dry pea have been consistently rising: from 36 percent of total world imports in 2011–13 (Table 7.3) to about 40 percent of total imports of pulses in recent years. In 2015–16, India imported dry pea from Canada (61 percent), Russia (15 percent), the USA (7 percent), France (5 percent) and Lithuania (4 percent) (Government of India, 2016).

There is very little direct consumption demand for dry pea in India. The import demand is mainly for yellow cotyledon dry pea, which is used to adulterate gram flour (*besan*).

Figure 7.8: Production and imports of dry pea, India, 1970 to 2013



Source: FAOSTAT data.

Conclusions

There has been a significant decline in the production of dry pea over the last three decades. This is a result of reduced demand for dry pea for direct human consumption and as a source of protein in animal feed. The largest use of dry pea for human consumption is in China, where it serves as a cheaper substitute for mung bean in vermicelli manufacture, and in India, where it is used to adulterate chickpea flour. In the developed countries of Europe, North America and Australia, dry pea is primarily used as a source of protein in animal feed. This demand has shrunk with increasing use of soybean as a cheaper substitute.

Europe was once the leading producer of dry pea. Disintegration of the Soviet Union resulted in a sharp decline in the production of dry pea in Russia and Ukraine, once the largest pea producers in Europe. Although cereals and livestock revived in Russia and Ukraine in the 2000s, production of pulses was increasingly marginalized. In Europe, introduction of price support in the late 1970s resulted in a significant growth in production of dry pea. However, withdrawal of price support in the 1990s and the eventual decoupling of agricultural support made dry pea production non-competitive as compared to domestic crops like wheat and barley, and to imports of soybean, soybean meal and dry pea from North America.

In contrast with trends in other regions of the world, production of dry pea has seen a continuous growth trend in North America. Since the 1990s, with large-scale mechanized farms, the opening up of trade and reduction of production subsidies in Europe, Canada has emerged as the biggest producer of dry pea in the world and has captured much of the global dry pea market.


CUSTOM BUILT BY
BILL'S WELDING
PULLMAN, WASHINGTON

PULSES OF THE VICIA GENUS

Prachi Bansal

The *Vicia* genus includes about 150 species of vetches, each with different characteristics and uses. Plants of the *Vicia* genus contain toxins like choline, guanidine, hydrocyanic acid, lysine, physostigmine, quercitrin, shikimic acid and xanthine to varying degrees (Duke, 1981). Of the various *Vicia* pulses, faba bean (*Vicia faba*) is the only one used for human consumption. Other *Vicia* genus legumes are grown for use as pastures, green manuring, livestock feed and as a cover crop in winter. Of these, the common vetch (*Vicia sativa L.*) is economically the most significant.

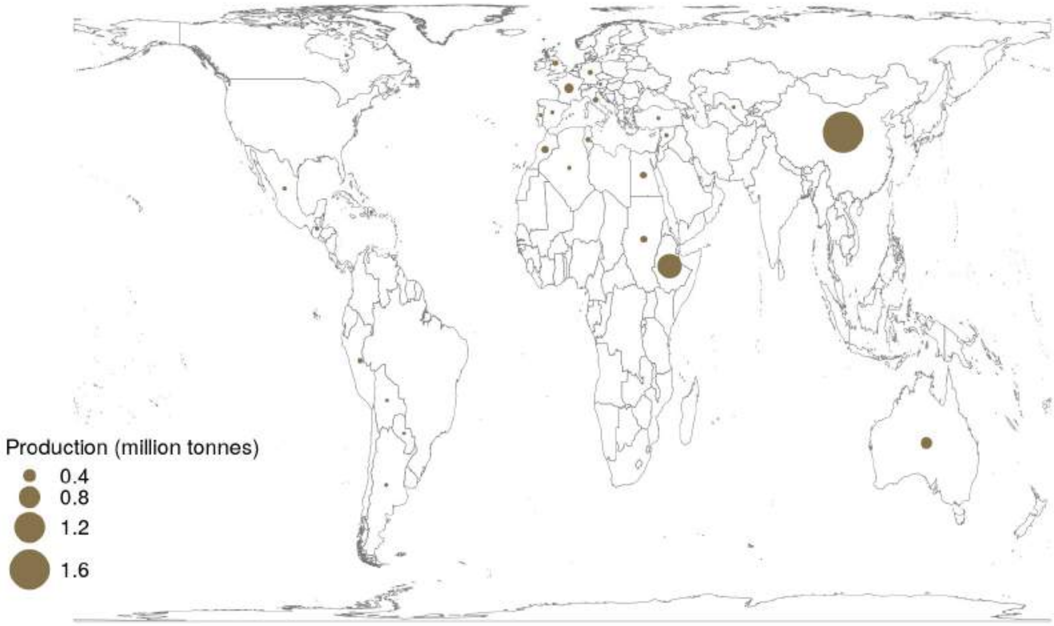
Faba Bean

Faba bean, the only edible pulse crop of the *Vicia* genus, is known by various names across the world, including broad bean, horse gram and fava bean. Three widely cultivated types of faba bean are *V. faba minor*, grown especially in Northern Europe; *V. faba equine*, grown in North Africa, the Middle East and Africa; and *V. faba major*, grown in China (Li-Juan *et al.*, 1993; Pratap and Kumar, 2011). These three types differ from each other primarily in respect of their seed-size. *V. faba major* is mainly used for human consumption, while *V. faba minor* is mainly used as livestock feed.

Faba bean is a cool season legume that affords several agro-ecosystem benefits, particularly when grown through crop rotation and intercropped with cereals like wheat and barley (Garrido and López-Bellido, 2001; Hauggaard-Nielsen, Peoples and Jensen, 2011; Köpke and Nemecek, 2010; Landry, Coyne and Hu, 2015).

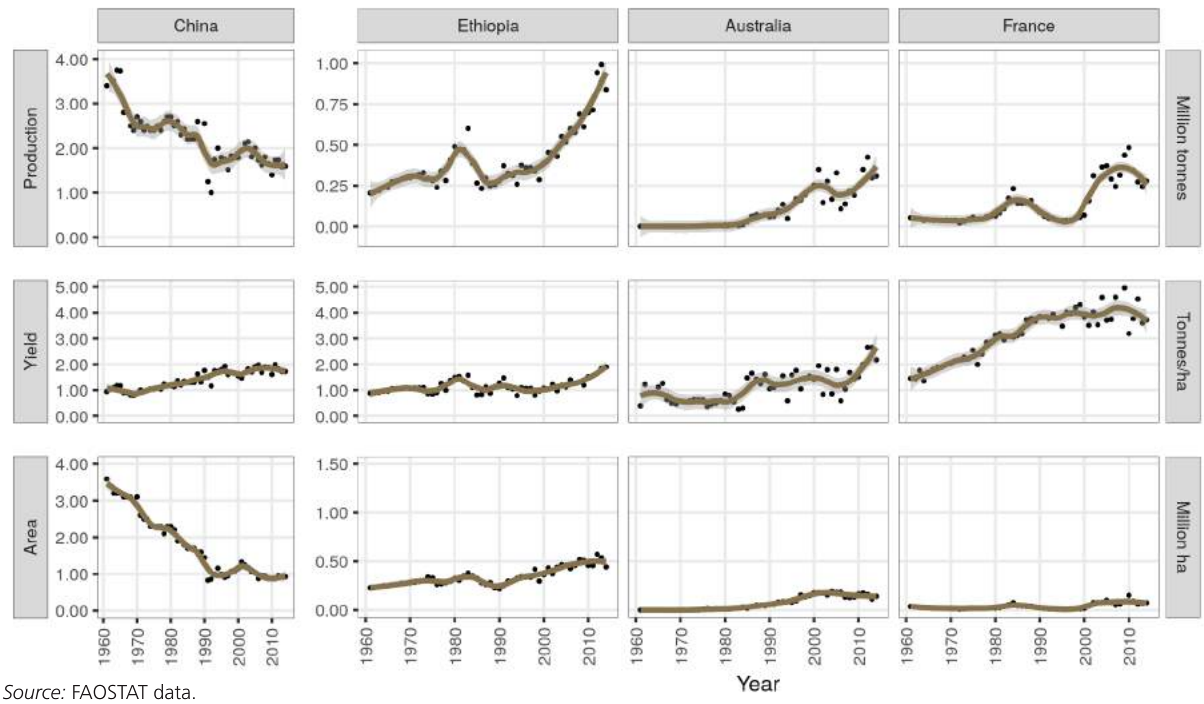
Faba bean is a traditional pulse crop in many parts of Asia and the Mediterranean region. However, it's cultivation has been steadily declining over the years and it has become a negligible crop in many countries. In the triennium ending 2014, 4.4 million tonnes of faba bean were produced globally. The share of land under faba bean in total area under cultivation of pulses fell from 8 percent in 1961–63 to 2.9 percent in 2012–14. Its share in total production of pulses also declined drastically in this period, from 12.4 percent to 5.7 percent.

Figure 8.1: Production of faba bean across different countries, 2012–14



Source: FAOSTAT data.

Figure 8.2: Production, yield and area harvested of faba bean, major producing countries, 1961 to 2014



Source: FAOSTAT data.

Globally, faba bean is mainly produced in China, Europe, Northern Africa, West Asia and Australia (Figure 8.1). China, where it is produced mainly for domestic consumption, is the largest producer of faba bean. In 2011–13, only 1 percent of Chinese faba bean production was exported. Figure 8.2 shows that there was a rapid fall in the production of faba bean in China between 1960 and 1990, from about 3.5 million tonnes produced annually in the early 1960s to about

Table 8.1: Average annual production, yield and area harvested of faba bean, major producing countries, 2012–14

Country	Production (million tonnes)	Yield (kilograms per hectare)	Area harvested (thousand hectares)	Share in world production (percent)
China	1.64	1755	933	37.26
Ethiopia	0.92	1793	519	21.03
Australia	0.34	2495	138	7.82
France	0.27	3953	68	6.05
Sudan	0.16	2138	74	3.59
Morocco	0.16	809	195	3.57
Egypt	0.15	3473	44	3.46
United Kingdom	0.11	5148	21	2.49
Italy	0.08	1910	43	1.88
Peru	0.08	1363	57	1.77
World	4.40	1807	2433	100.00

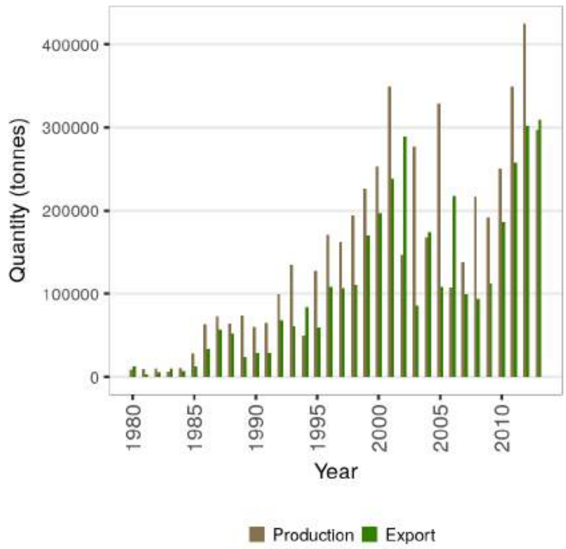
Source: FAOSTAT data.

2 million tonnes by the early 1990s – and further to about 1.6 million tonnes by 2014. The decline in China's faba bean production is a result of the shift of land away from faba bean cultivation towards wheat and barley (Li-Juan *et al.*, 1993).

While faba bean production has declined in China, there has been an increase in production in Africa and Australia (Figure 8.2). In Africa, Ethiopia is the largest producer of faba bean (Table 8.1), with production growing at a rate of about 5 percent per annum between 1990 and 2014. Almost 58 percent of the growth of production in Ethiopia was on account of an expansion in the area under faba bean, and the rest was a result of an increase in yields. The area sown with faba bean here more than doubled, from 0.23 million hectares to 0.51 million hectares, between 1989–91 and 2012–14.

Faba bean production in Australia is mainly aimed at meeting demand from the Middle East (Keogh, Robinson and Mullins, 2010). In 2011–13, Australia exported nearly 80 percent of its annual production of about 0.36 million tonnes (Figure 8.3). Egypt is the major importer of faba bean from the country, followed by Saudi Arabia, United Arab Emirates and Indonesia. Domestically, faba bean is used in Australia mainly as livestock feed.

Figure 8.3: Production and exports of faba bean, Australia, 1980 to 2013



Source: FAOSTAT data.

Faba bean and other plants of the *Vicia* genus, unlike most other pulses, are grown through

Table 8.2: Gross value of output, costs and gross margin of faba bean, Australia, Sudan (equivalent kilograms of faba bean)

Output, costs and gross margin	Australia (2015)			Sudan (2013–14)
	Low rainfall zone	Medium rainfall zone	High rainfall zone	River Nile State
Output				
Gross value of output	253	505	884	1396
Yield (kilograms per hectare)	800	1600	2800	1600
Price (USD per kilogram)	0.32	0.32	0.32	0.87
Variable costs				
Seed	117	128	152	256
Fertilizer	73	110	147	0
Plant protection	202	321	347	40
Machinery (fuel and repairs)	82	98	114	10
Labour				332
Irrigation				75
Insurance	10	19	34	0
Levies	14	29	50	3
Bagging				19
Total variable costs	498	705	844	735
Gross margin at farm gate				
Gross margin	302	895	1956	865
Gross margin (USD per kilogram)	95	283	618	755

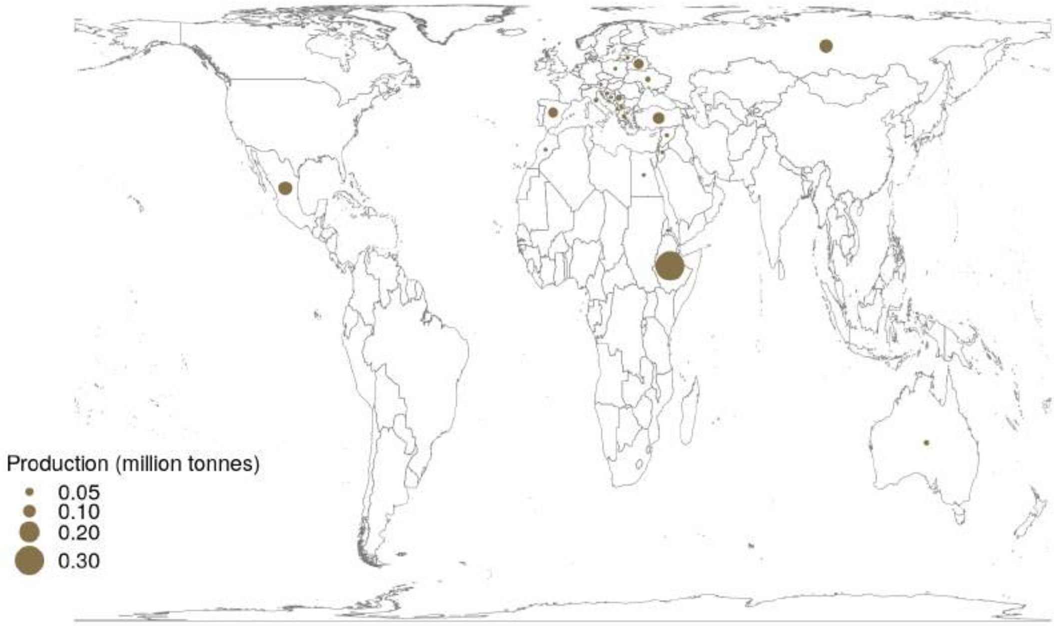
Source: Government of South Australia (2015); Mohammed, Khalifa and Ibrahim (2015).

a considerable degree of cross-pollination facilitated by bees. This has led to considerable advance in breeding high-yielding varieties of faba bean, though efforts to produce hybrids have not been successful so far (Bishnoi *et al.*, 2012; Duc, 1997; Hawtin and Webb, 1982; Maalouf, 2011). Internationally, breeding research on faba bean is led by the International Center for Agricultural Research in the Dry Areas (ICARDA).

It is noteworthy that yields of faba bean are higher than that of most other grain legumes. In 2012–14, the average global yield of faba bean was 1,807 kilograms per hectare (Table 8.1). However, given low prices, returns from faba bean production are low and have been falling. Consequently, other cool season legumes like chickpea and lentil are increasingly preferred for cultivation over faba bean.

Data on costs of production and margins in faba bean production are not available for most major producing countries. Table 8.2 presents data on costs and margins for three zones of Australia, and for one state in Sudan. There is a large variation in faba bean yields across the three rainfall zones in Australia, and seed, fertilizer and plant protection chemicals constitute the major items in the cost of production of faba bean. On the other hand, in River Nile State in Sudan, labour and seeds were the most important items of cost. The average yield of faba bean in Australia, 2,495 kilograms per hectare in 2012-14, is close to the yield achievable in the high

Figure 8.4: Production of common vetch across different countries, 2012–14



Source: FAOSTAT data.

rainfall zone. In this zone, with a yield of 2,800 kilograms per hectare, the gross margin is about 69 percent of the total output. In River Nile State in Sudan, the gross margin was 54 percent of total output. However, the price of faba bean was much higher in Sudan than in Australia, resulting in a much higher dollar value of gross margin in Sudan than in Australia.

Common Vetch

Common vetch is another extensively grown pulse of the *Vicia* genus. It is a winter season legume grown mainly for hay, silage, pasture, green manure, biomass and seed. Inclusion of common vetch in animal feed has been found to improve the weight and health of livestock (Velazquez-Beltran, Felipe-Perez and Arriaga-Jordan, 2002). Seeds of common vetch can also be used for medicinal purposes (Duke, 1981). Common vetch is thus an extremely versatile crop, grown mainly in Europe and sub-Saharan Africa (Figure 8.4). It adapts well to a wide range of soils, from light sandy to heavy clay. It grows in both low-rainfall and high-rainfall areas, and different varieties can adapt to warm and cold environments. The plant has a deep tap root system, making it suitable for cultivation in semi-arid and low-rainfall regions of the world.

The grain of common vetch is not used for human consumption because of the presence of toxicity. In the past, however, there have been instances of adulteration of lentils with similar-looking common vetch varieties.

Common vetch is mainly used for pasturing. However, only some varieties can be fed to animals. Varieties susceptible to rust, especially, can induce abortion in pregnant livestock (Matic, Nagel and Kirby, 2015).

FAOSTAT data on common vetch show that there has been a sharp decline in its production, from 2.15 million tonnes in the triennium ending 1971 to 0.92 million tonnes in the triennium ending 2014. This was primarily on account of a shift to other leguminous crops for use as livestock feed.

Ethiopia, Mexico, Russia and Turkey together account for approximately 68 percent of the global production of common vetch. Other producing countries include Spain, Belarus, Serbia, Ukraine and Australia (Table 8.3). Ethiopia accounts for 32 percent of the total production of vetches in the world. Vetch occupies an important place in pulse farming in Ethiopia, contributing to 11 percent of total production in 2012–14. It is one of the few countries of the world where vetch production has expanded substantially over the

Table 8.3: Average annual production and area harvested of common vetch, major producing countries, 2012–14

Country	Production (million tonnes)	Area harvested (thousand hectares)	Share in world production (percent)
Ethiopia	0.30	171	32.46
Mexico	0.12	8	12.64
Russian Federation	0.11	81	12.42
Turkey	0.09	81	10.33
Spain	0.07	81	8.14
Belarus	0.07	28	7.69
Serbia	0.03	9	2.92
Ukraine	0.02	13	2.66
Australia	0.02	48	2.10
Jordan	0.01	2	1.26
World	0.92	587	100.00

Source: FAOSTAT data.

last two decades: from 0.05 million tonnes in the triennium ending 1995 to 0.3 million tonnes in the triennium ending 2014. Common vetch is grown mainly in the black soils of the Ethiopian highlands for use as forage, and is preferred as animal feed over other forage crops because of its high crude protein content. In view of the poor nutritional status of livestock and recognizing the important role that forage legumes can play in meeting their protein requirement, the Livestock Development Project of the Ministry of Agriculture of Ethiopia initiated a policy of promoting inclusion of forage legumes in crop production systems (The World Bank, 1996).

Mexico is the second largest producer of common vetch in the world, with an annual production figure of 0.12 million tonnes in 2012–14. Vetches are an emerging source of feedstock in the hilly areas of Central Mexico, where smallholder livestock farmers grow them as a cheaper substitute to livestock feed concentrates. Oats-vetch silage is also increasingly preferred over the traditional maize silage in the smallholder *campesino* farms of Central Mexico because of the former's higher protein content (Guadarrama-Estrada *et al.,* 2007).

Common vetch, hairy vetch and Russian vetch are all grown extensively in Russia. Common vetch production in Russia was about 0.11 million tonnes in the triennium ending 2014.

Conclusions

Pulses of the *Vicia* genus are amongst the most neglected legumes (Mikić and Mihailović, 2015). Of the various *Vicia* legumes, only faba bean is used for human consumption. Other types of vetch are unsuitable for direct human consumption because they contain high levels of toxins. Faba bean, common vetch and other legumes of the *Vicia* genus are grown mainly for use as livestock feed, forage crops, green manure and winter cover. Globally, about 4.4 million tonnes of faba bean and about 0.92 million tonnes of common vetch were produced in the triennium ending 2014. Production of both these pulses has declined globally over the last two decades. At present, China is the biggest producer of faba bean and Ethiopia is the largest producer of common vetch.

VALUE CHAINS AND MARKETS

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with contributions from Robert Burden

Introduction

Post-harvest value chains are a critical component of the global pulse economy. Pulses undergo several post-harvest processes – such as threshing, winnowing, cleaning, drying, sorting, splitting, dehulling, milling and fractionating – before they are ready to be used for cooking in homes or as ingredients in processed foods. The post-harvest value chains of pulses may also include the preparation of products like noodles, baked and canned beans, and different types of snacks that are packaged for retail. The nature of the value chain varies by the type of pulse, the kind of farm on which it is produced and the form in which it is consumed. Post-harvest value chains of pulses can broadly be classified into three types.

First, in countries with large-scale export-oriented production of pulses, the main post-harvest operations are cleaning, grading, storage, bagging and transportation. Given the large scale of production, the value chain in the country of origin typically involves the producer and a firm that does primary processing and exports. It has also been found, in many instances, that large farmers themselves have established facilities for some of the post-harvest operations, as well as, in a few cases, expanded into the business of exports.

Secondly, in countries where pulses are produced on smallholder farms and are then exported or consumed in the form of whole grain, the post-harvest operations involve cleaning, grading, bagging and transportation, along with several stages of trading. The length of the value chain, or the number of trading agents between the producer and the consumer, may vary considerably across countries and types of producers.

Thirdly, in the Indian subcontinent, where about 75 percent of pulses consumed are in the form of split grain, split and dehulled grain, and flour, processing and milling occupy critical positions in the post-harvest value chains. Apart from pulse-processing mills, the value chains here include different types of traders and commission agents, importers, wholesalers and retailers.

This chapter presents an analysis of value chains in the production of pulses in selected countries and regions of the world. It describes the structure of these value chains, and of price formation along the chains and in different types of markets.

Value Chains of Pulses in Canada

Lentil

Value chains of pulses in Canada are relatively short. Once the lentil has been harvested from the field, it is generally stored in grain silos until sale. A small proportion is reserved for seed and the remaining quantity of harvested lentil is transported to the buyer's location, where it is cleaned, elevated and stored. Some of the lentil undergoes further processing, including colour-sorting, decortication, splitting, polishing and sometimes packaging. Secondary processing may also include extraction of starch, protein and fibre from the lentil.

Lentil produced in Canada is processed both domestically and in the importing countries. Generally, at least the primary processing of the raw product is done within Canada. This helps reduce freight costs, and is also important for adhering to sanitary and phyto-sanitary regulations associated with trade. Until recently, secondary processing of Canadian lentil was done almost entirely in importing countries like India, Turkey and West Asian countries, which had significantly more experience in processing and were able to process the lentil at lower costs.

A more recent trend has been for lentil produced in Canada to be processed within the country itself. Accordingly, companies like AGT Food and Ingredients (AGT) have invested heavily in setting up processing facilities. As yet, however, only a small proportion of Canadian lentil goes through secondary processing in Canada.

Vertical integration in the lentil-processing industry has resulted in shorter and more consolidated value chains. This is consistent with consolidation within the agricultural value chain as a whole, and has resulted in fewer and larger companies. With some of the biggest players in the lentil trade based in Canada, there is significant primary-processing capacity in Alberta and Saskatchewan. Archer Daniels Midland (ADM), Viterra and AGT are among the large Canadian companies engaged in purchase and trade of lentil. Other buyers include Export Trading Company (ETG), ILTA Grain, Agrocorp and Hakan Agro. Some of these entities (for example, Viterra, ADM and Scoular) are involved only in primary processing followed by sale of the semi-refined product, while others (for example, AGT and Columbia Grain) engage in all stages of processing. AGT is the world's largest lentil-processing company and plays a major role in Canada's lentil value chain. The R.B. Group in India – which is vertically integrated and engaged in all activities from procurement to retail – is also a major player in the global lentil industry.

The general trend in the global pulses trade is towards greater use of bulk shipments as compared to container vessels (Pratt, 2016). This trend may be attributed to a couple of factors. First, there has been increased participation in the pulses industry of big grain companies like Viterra and ADM, which transport large quantities of grain and tend to rely primarily on bulk vessels. Secondly, bulk shipping rates today are at a historical low and have fallen more steeply than container shipping rates. The Baltic Dry Index (BDI), which measures trends in average cost to move large quantities of commodity products via bulk vessels, shows that bulk freight costs have been falling since 2008 and reached a historical low in the first half of 2016.[1] Pratt (2016) argues that bulk vessel companies tend to be smaller than container companies, and, given the limitation of bulk vessel companies not having enough capacity to keep ships idle, bulk shipping rates fell steeply in the wake of the global economic slowdown. In comparison, given their much bigger firm size and thus higher capacity to keep ships idle, container companies were better able to mitigate the effects of sluggish demand.

1 https://www.bloomberg.com/quote/BDIY:IND

Dry pea

Of all pulses, the value chain of dry pea is unique because a significant proportion of dry pea produced the world over is used as livestock feed. This use significantly reduces the extent of value addition in it's value chain. Canada, China and Russia are the largest producers of dry pea in the world. Of the total quantity of dry pea produced in Canada, it is estimated that approximately 14 percent is kept for use as seed and about 20 percent as feed for own livestock. About 66 percent of total Canadian dry pea production in 2013 was handled by grain elevators or processors (Serecon Inc, 2016).

Once the harvested peas have been cleaned and stored, they are either exported or processed for domestic consumption. Secondary processing of peas includes cleaning, splitting, polishing and packaging, after which the peas are shipped to a wholesaler for onward redistribution to retailers and consumers. Many of the large multinational companies in Canada, such as ADM, Cargill, Glencore, Bunge and Richardson, are engaged in exporting peas. AGT is a major buyer and exporter of processed peas, and has one of the largest pea-splitting facilities in the world. There are also numerous smaller, family-operated processing facilities for splitting peas.

Large trading multinationals play an important role in sourcing peas from the major producing regions for international buyers. Vermicelli noodle buyers import the raw product and perform the processing on their own. There is little demand for processed peas in China. In India, another major importer of dry pea for human consumption, dry pea flour is added to chickpea flour as a cheap substitute.

Given low ocean freight rates, in particular of bulk vessels, a trend towards bulk shipments is observed in the global pea trade as well. Feed-grade pea for livestock is transported by bulk vessels as breakage is not a critical factor. However, edible pea shipments are typically transported in bulk container loads to reduce breakage and protect the cleanliness of the product.

Value Chains of Pulses in Africa

Agricultural markets in Africa are characterized by imperfections such as poor infrastructure, lack of formal market mechanisms and consequent reliance on informal trade networks. Common bean, cowpea and pigeonpea are the major pulses grown in Africa. The post-harvest value chain consists of village collectors who purchase pulses from smallholder producers and pack them in bags, and traders who procure bags of pulses from these village collectors to sell either in urban trading centres or to exporters. Only a few large trading firms have the capacity for processes like dehulling, splitting, cleaning and canning.

Common bean is mostly sold as dry bean and a small proportion as fresh pods. Smallholder subsistence farmers produce pulses mainly for domestic consumption and the surplus, if any, is sold to village collectors. In most countries of Africa, smallholder producers of pulses lack access to improved seeds and other modern inputs. The International Trade Centre (2015) shows that less than 0.5 percent of seeds used by farmers in Tanzania are certified seeds. The major reasons for low adoption of improved seeds are limited supply, low seed multiplication capacity, poor dissemination, high costs and limited awareness of farmers about the released varieties. Farmers use their own seeds and often engage in exchange of seeds locally (Chemonics International Inc., 2010). Mostly, only large-scale commercial farmers who grow beans for exports under contract farming arrangements have access to improved seed varieties. The level of application of fertilizers and plant protection chemicals is low among smallholder producers, and pulses are produced by them using family labour and with minimal investment. Since smallholder producers have limited access to on-farm storage capacity and pulses are highly susceptible to storage pests, producers without proper storage facilities are forced to sell their produce immediately after harvest or are subject to substantial post-harvest losses. In Ethiopia, for instance, post-harvest losses have been estimated to be in the range of 15 to 20 percent of total production (Rashid *et al.*, 2015).

Given the lack of institutional buyers such as government cooperatives, the produce is sold to village collectors who act as middlemen between the producers and traders. Kilimo Trust (2012) found that 69 percent of bean production by producers in Uganda is sold to village collectors and only 5 percent to institutional buyers. The village collectors collect the grain in bags and transport the bags to local traders, who get the grain cleaned and sorted. Only a few traders have facilities for dehulling and splitting the grain. Small traders sell in the local market and engage very little in processing activities, while large-scale traders often have contacts with exporters who trade in large volumes within and outside Africa. Border traders sell produce from large pulse-producing countries, like Ethiopia and Tanzania, to other countries in Africa (Chemining'wa, Kitonyo and Nderitu, 2014). They operate like wholesalers and buy bulk quantities for intra-regional, cross-country trade. There are very few African processing firms that have facilities for canning beans and making bean flour. In Uganda, for example, less than 1 percent of the total beans is industry-processed (Kilimo Trust, 2012).

Exporters do sorting and splitting of grains depending on the requirements of the importing countries. Maintaining the quality of the grain is an important concern at this stage of the value chain. In Ethiopia, 10 to 25 percent of the produce is lost due to poor quality (Rashid *et al.,* 2015). Ever since India started to import substantial quantities of pulses from sub-Saharan Africa, Indian investors have begun to invest in pulse-processing industries in Tanzania, Mozambique and Ethiopia. These firms obtain grains from smallholder producers through contract farming arrangements.

Market prices of pulses and pulse products increase as they move along the value chain. Returns that accrue on account of this increase in market value are shared by different actors along the value chain in different proportions. Although country-level data on prices along the value chain are not available, micro-level studies within countries provide useful insights. A study in Uganda, for instance, found that in the value sub-chain of bean flour, processors received 48 percent, retailers received 25 percent and open market traders received 27 percent of the final price paid by the consumer (Kilimo Trust, 2012).

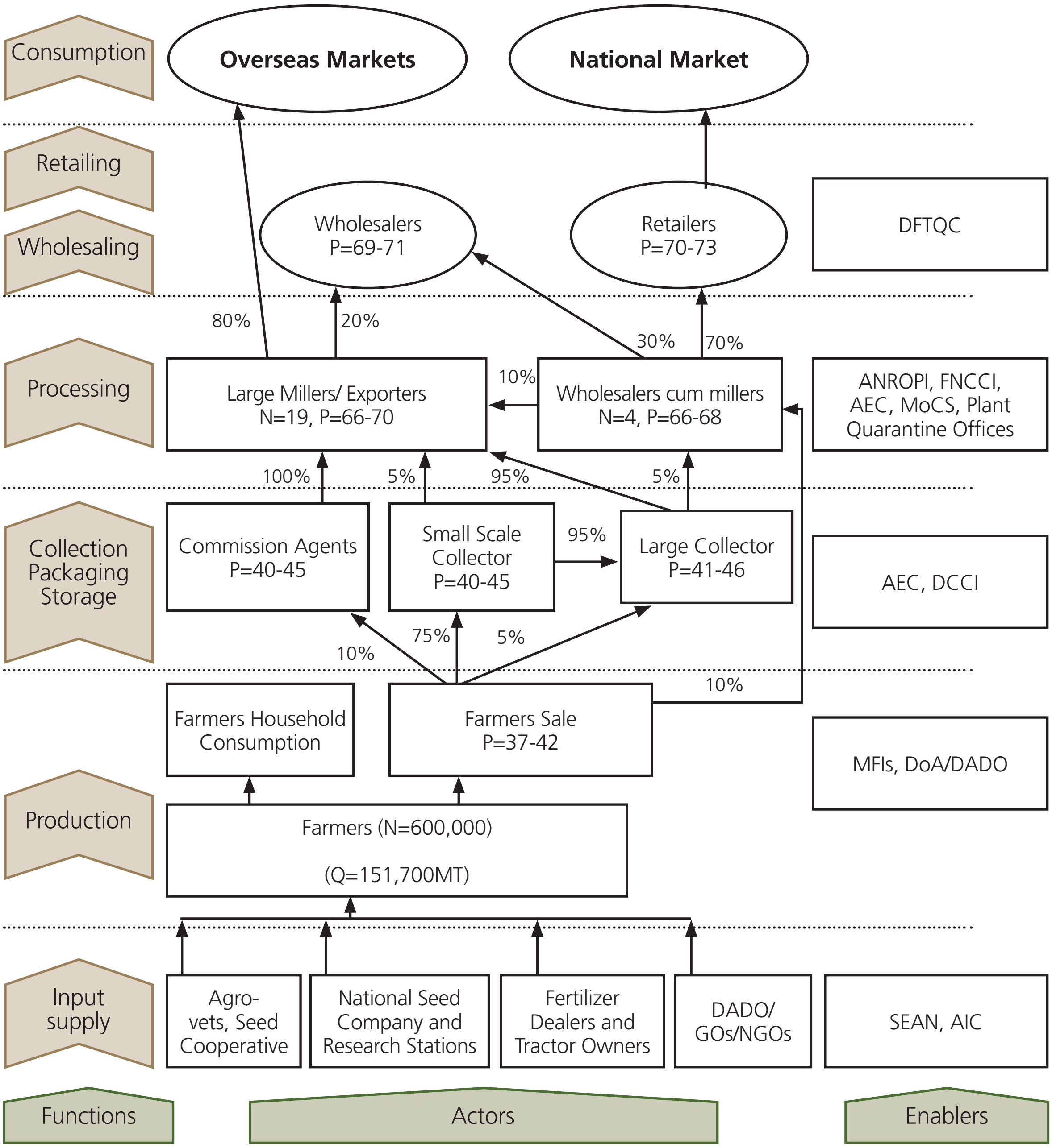
Value Chains of Pulses in South Asia

Pulse value chains in South Asia have two distinctive characteristics. First, the bulk of pulses consumed here are in the form of split grain, dehulled grain or as flour. As a result, milling of pulses is an important part of the value chains. Secondly, pulses in South Asia are produced on a large number of tiny farms, and reach the market passing through a long chain of intermediaries comprising village-level traders/aggregators, commission agents, millers, wholesalers and retailers (see Figure 9.1). Most commonly, small producers sell their output at the farm level to commission agents, small traders or large farmers, who perform the role of aggregators, collecting produce from several farms before transporting them for sale to larger wholesale markets. Occasionally, producers also sell the grain directly to consumers within the village or at weekly markets in nearby villages. Since smallholder producers are generally in need of money for their immediate consumption expenses as well as for investing in the next crop, most of the produce is sold by them immediately after the harvest and only a small proportion is stored at the farm for sale later in anticipation of a higher price. Relatively larger farmers undertake the journey to local markets to sell their produce to wholesale traders. Pulses move between multiple levels of wholesalers before reaching a pulse-milling/processing facility. After milling, the grain and flour, the main forms in which pulses are consumed in India, again pass through a chain of intermediaries, including wholesalers and retailers, before they reach the hands of consumers.

Post-harvest value chains of pulses in South Asia also involve considerable losses. In India, nationally representative surveys have shown that harvest and post-harvest losses for pulses are in the range of 6 to 8 percent of production, which is higher than the losses for cereals (Box 9.1).

Public procurement and distribution programmes and schemes, although large in some of the South Asian countries, do not cover pulses to any significant degree. Only a negligible proportion of pulses is procured under public

Figure 9.1: Value chain map of lentil in Nepal



Note: N=number of actors; Q = quantity of lentil in million tonnes; P=price of lentil in Nepali Rupee per kilogram
Source: ANSAB (2011).

procurement programmes. In India, the National Agricultural Cooperative Marketing Federation of India (NAFED) is the nodal agency for procurement of pulses. Although the minimum support prices (MSP) for pulses have been rising in recent years, they are lower than prevailing market prices (Mohanty and Satyasai, 2015). Given this, only 1–4 percent of the total quantity of pulses produced in India is procured through public agencies like NAFED. To put this in perspective, about 30 percent of cereals produced in India in 2012–15 was procured by government agencies (Commission for Agricultural Costs and Prices, 2015).

Due to low public procurement prices or/and absence of procurement operations, most farmers sell their crops to private traders and commission agents. The value chains for agricultural commodities in South Asia involve a number of intermediaries between the farmer

Box 9.1: Post-harvest losses of pulses in India

Substantial losses take place during post-harvest processing of pulses in India. In recent years, the All-India Coordinated Research Project on Post Harvest Technology of the Indian Council of Agricultural Research (ICAR) has done two national-level assessments, for 2005–06 and 2013–14, of post-harvest losses of agricultural crops including pulse crops (Jha *et al.*, 2015; Nanda *et al.*, 2012). In 2013–14, total post-harvest losses were estimated to be 8.4 percent of production for chickpea and 6.4 percent of production for pigeonpea. Harvesting, threshing, storage at farm and milling in processing units were identified as major contributors to post-harvest losses (Jha *et al.*, 2015). Storage losses ranged from 1.18 percent of production for chickpea and black gram, to 1.67 percent of production for pigeonpea. Post-harvest losses for pulses were estimated to be higher than for cereals but lower than for fresh fruits and vegetables (Box Table 9.1). Over 50 percent of storage losses were estimated to be at the farm level, because of poor storage facilities.

The use of ill-suited threshing machines, delayed harvesting and improper storage practices were cited as reasons for high levels of losses in pulses. Unseasonal rains at the time of harvesting cause significant losses. Mechanization of threshing has become popular in recent decades. However, while the move towards use of high-capacity wheat threshers for pulses is cost-effective, the operating conditions and machine parameters under which wheat threshers are used is not suitable for threshing of pulses. Considerable losses also take place during storage because of poor infrastructure, especially at the farm level. Support for improvement of farm-level storage infrastructure is crucial for reducing storage losses of pulses.

Box Table 9.1: Estimated harvest and post-harvest losses as a proportion of production, pulses and other selected agricultural commodities in India, 2013–14 (percent)

Crop	2013–14
Pulses	
Pigeonpea	6.4
Chickpea	8.4
Urd bean	7.1
Mung bean	6.6
Cereals	
Paddy	5.5
Wheat	4.9
Oilseeds	
Soybean	10.0
Groundnut	6.0
Mustard	5.5
Fruits and vegetables	
Apple	10.4
Banana	7.7
Mango	9.2
Potato	7.7
Tomato	12.4
Cauliflower	9.5

Source: Based on Tables 6.1–6.4 of Jha *et al.* (2015).

and the final consumer (ANSAB, 2011; Hegde, 2012; Kumar and Husain, 1998; Shalendra, 2012). The main actors in the value chains of pulses between the farmer and the consumer are: multiple village-level commission agents, traders and aggregators; traders at the local market or *mandi*; processor or miller; multiple levels of wholesalers of processed pulses; and retailer.

As pulses move from the farm to the consumer through these various levels of traders, processing mills, wholesalers and retailers, their prices rise on account of expenses incurred on transport, processing, storage and marketing, and on account of margins at all levels along the value chain. Table 9.1 presents Indian data on appreciation in market value using cost of production, farm-gate prices, wholesale prices and retail prices for 2013. Using these data, one can examine the extent of appreciation in market value at different stages. While data are not available on costs incurred at each stage of the value chain, the extent of appreciation in market value does give an indication of the extent of margins. The table shows that the median difference between retail prices and cost of cultivation varied considerably across pulses. In 2013, the median percentage difference between retail price and cost of cultivation was largest for lentil (67 percent of cost of cultivation) and pigeonpea (61 percent of cost of cultivation).

Table 9.1: Median percentage difference between retail prices and cost of cultivation, and its distribution across different stages of the value chain, India, 2013 (percent)

Crop	Farmers	Processors and wholesale traders	Retailers	Total
Pigeonpea	22	15	24	61
Chickpea	13	18	1	32
Lentil	29	19	19	67
Mung bean	10	9	5	24
Urd bean	-21	9	6	-5

Note: The estimates are based on a conversion ratio of 0.76 from whole grain to processed pulses.
Source: Data on costs of production, farm harvest prices, retail prices and wholesale prices from Ministry of Agriculture, Government of India.

On the other hand, in the case of urd bean, the retail price was 5 percent less than the cost of production.

Assessment of the spread of this appreciation in market value must be done keeping in mind the fact that the volume of pulses handled by agents at different stages of the value chain varies a great deal. While an average producer with less than 1 hectare of land produces only a few quintals of pulses, a large pulse-processing firm processes millions of tonnes of pulses annually. A typical small retailer sells only a few tonnes of pulses annually but deals in many other commodities as well.

Given the very small scale of production, substantial per unit margins are necessary for even meagre absolute returns to accrue to smallholder producers. In India, producer margins over total cost of cultivation were highest for lentil (29 percent) and pigeonpea (22 percent). Median percentage margins of urd bean producers were negative in 2013. The percentage difference between market value at the farm-gate and the wholesale market varied a great deal across different pulse crops. The appreciation in market value between farm-gate and wholesale market was highest for pigeonpea and lentil, and lowest for mung bean and urd bean. It must be noted that although there are multiple layers of traders and processors between the farm-gate and the wholesale market, each agent in this segment of the chain deals with much larger volumes than both farmers and retailers. In the case of pigeonpea and lentil, substantial price appreciation also took place between wholesale and retail markets. It is to be noted that in 2013 in India, median retail prices were lower than the median cost of production of urd bean. However, the losses on account of this were entirely borne by smallholder producers, and prices appreciated in the value chain from farm-gate onwards.

The Pulse-Milling Industry in India

India's pulse-milling industry is the largest in the world. About 76 percent of global processing and milling capacity of pulses is located in India (Table 9.2). In 2005–06, the last year for which data are available for the entire industry, there were about 14,000 pulse-milling firms in India.

The process of milling involves splitting, and optionally also dehulling, of the pulse grain. The process could lead to losses in the form of broken splits and powder, which can be minimized by improving the efficiency of milling operations. In the case of chickpea, a substantial part is also turned into flour during milling.

Traditionally, pulses are split and dehulled at home using different types of hand-pounding equipment. In the early 1950s, there were about 500 mills engaged in commercial processing of pulses in India. In 1967, as part of the industrial development policy that sought to protect and promote the small-scale sector, pulse-milling was reserved for the small-scale sector and large-scale investment in pulse-milling factories was not allowed. During the 1970s and 1980s, governmental

Table 9.2: Pulse-processing and milling capacity, by country, 2015–16 (thousand tonnes)

Country	Processing and milling capacity
India	18000
Canada	2000
Turkey	1000
Myanmar	1000
Australia	500
United Arab Emirates	400
China	400
Egypt	200
Rest of the World	250
Total	23750

Source: Serecon Inc. (2016).

support was provided to the small-scale pulse-milling industry in the form of R&D activity for development of improved milling technology, and provision of credit as part of priority sectors to facilitate technological upgradation and improvement in milling efficiency. Research on pulse-processing and storage technology was undertaken in the Central Institute of Agricultural Engineering (CIAE), Central Food Technological Research Institute (CFTRI), Indian Institute of Pulses Research (IIPR) and many agricultural universities. These institutions developed improved designs for machinery used in pulse-processing involving low capital requirement and high levels of operational efficiency, and this resulted in considerable improvements in pulse-processing efficiency in the 1970s and 1980s (Kachru, 2006; Singh, Gupta and Singh, 2003).

Although technical efficiency in milling technology improved considerably in this period, small-scale pulse-milling firms sourced raw pulses only locally and, because of seasonal availability of raw pulses, suffered from low capacity utilization for a large part of the year (Desale *et al.*, 2003; Gauraha, Srivastava and Mathur, 2003; Kachru, 2006; Malik *et al.*, 2009).

The processing of pulses was de-reserved and opened up to large-scale enterprises in 1997. Since then, both the number of large enterprises and their share in total production of processed pulses have increased sharply. The latest industrial surveys from which data on the pulse-processing industry as a whole (including both organized-sector and unorganized-sector firms) can be obtained are for 2005–06.[2] Analysis of these data shows that although small, unorganized-sector enterprises constitute a large proportion of the firms, they account for a relatively small share in the total volume of pulses processed. De-reservation of the pulse-processing industry since 1997 has resulted in the emergence of large pulse-processing enterprises, which now dominate the handling of pulses produced in India. In 2005–06, there were over 100 large pulse-milling enterprises in the country with fixed assets of over Rs 10 million (about USD 230,000 at 2005–06 exchange rate) each.

Table 9.3 gives the distribution of enterprises and output in the pulse-processing industry of India by size-classes of fixed capital for the year 2005–06. As seen from the table, 66 percent of the enterprises had fixed capital of less than Rs 0.1 million (USD 2,300 at 2005–06 exchange rate) each. These micro-enterprises accounted for only 3 percent of the total produce of the pulse-processing industry, processing only about 30 tonnes of pulses per year on average. Small enterprises with fixed capital between Rs 0.1 million to Rs 1 million constituted about 22 percent of all enterprises, and accounted for about 23 percent of processed pulses. Medium-sized enterprises with fixed capital of Rs 1–10 million accounted for about 58 percent of total pulses processed by the industry. At the other end of the spectrum, large enterprises with

2 The last national survey of enterprises in the unorganized sector was conducted in 2005–06, while surveys of enterprises in the organized factory sector are conducted every year by the Central Statistical Office (CSO). Combining these two sources, one can get a snapshot of India's pulse-processing industry in 2005–06.

Table 9.3: Number of enterprises and quantity of pulses processed, by size-class of fixed capital, India, 2005–06

Size-class (Rs)	Enterprises		Share in quantity of pulses processed
	Number	Share (percent)	(percent)
Less than 0.1 million	9402	66.0	2.9
0.1–1 million	3168	22.2	23.0
1–5 million	1455	10.2	45.5
5–10 million	109	0.8	12.3
>10 million	105	0.7	16.3
All firms	14239	100.0	100.0

Source: Estimated using unit-level data of the Unorganized Manufacturing Enterprises Survey (62nd round) conducted by the National Sample Survey Organization (NSSO), and unit-level data of the *Annual Survey of Industries*, 2005–06.

fixed capital of over Rs 10 million accounted for less than 1 percent of total enterprises in the pulse-processing sector, but processed about 16.3 percent of the total produce. These large enterprises accounted for 71 percent of the whole grain and 38 percent of the pulse flour sold by pulse-processing enterprises.

This trend of increasing scale of processing enterprises has continued after 2005–06 as well. Data from 2005–06 onwards are available only for the organized (factory) sector. These data, presented in Table 9.4, show that the trend of increasing concentration has continued in the pulse-processing industry. Within the factory sector, the share of pulses processed by the largest 10 percent of firms increased from 15 percent in 1997 to about 30 percent in 2005, and further to 40 percent in 2013.

To sum up, there has been considerable growth of the pulse-processing industry in India. It is currently estimated to have the capacity to process 18 million tonnes of pulses. In the 1970s and 1980s, public-sector R&D organizations played an important instrumental role in the technological upgradation of small-scale pulse-processing enterprises. Since 1997, when India opened its pulse-processing industry to large-scale investment, there has been a consistent trend of increasing concentration and large firms now account for a substantial share in the total quantity of pulses processed.

Table 9.4: Share in quantity of pulses processed by the factory sector, enterprises in deciles of fixed capital, India, 1997, 2005 and 2013 (percent)

Deciles	1997	2005	2013
D1	1	3	1
D2	4	7	3
D3	5	6	3
D4	44	6	3
D5	2	4	8
D6	8	9	6
D7	7	12	15
D8	8	6	15
D9	7	15	9
D10	15	31	40

Source: Data from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

Futures Markets of Pulses in India

Futures contracts provide the facility to hedge against unfavourable price movements in the future as prices for future transactions are fixed beforehand. In a futures contract, the trading parties freeze the price for a future date on which delivery is promised at the time of the transaction by selling/buying futures, and thus can mitigate the risk of price uncertainty. In addition, the futures market can also serve the function of revealing market participants' perception about spot prices expected in the future. Futures contracts are traded in exchanges, which allow the contracting parties to square off their position before the maturity of the contract and provide anonymity to the trading parties.

Over the last decade or so, India has experimented with commodity futures markets for different pulses. In 2004, futures trading was allowed for a number of pulses on three national multi-commodity exchanges in India. Of the various pulses, chickpea futures were the most liquid and were traded from April 2004 to July 2016, with a brief period of suspension of trade during July–December 2008. Commodity futures for mung bean, urd bean and pigeonpea were relatively less liquid, and were suspended in 2007. Over the years, the Forward Markets Commission (FMC), and later the Securities and Exchange Board of India (SEBI) with which the FMC was merged, imposed several restrictions to limit speculative activity in futures trading of agricultural commodities. Foreign investments are not allowed in commodity markets in India. For pulses, limits were imposed on the total open position of an individual client and a member. There were also limits on daily price fluctuations. On expiry of the contract, all outstanding positions not resulting in giving/taking of physical delivery of the commodity were closed at the final settlement price announced by the exchange. For contracts of most agricultural commodities including chickpea, it was made compulsory that outstanding positions on the maturity of the contracts end in deliveries, with a penalty for failure to provide/accept delivery. Given the large gap between demand and supply, rising prices of pulses, and claims of excessive speculative activity in commodity futures of pulses, SEBI decided to stop futures trading of pulses from July 2016.

Appendix 9.1 presents detailed statistical analysis of chickpea prices in futures and spot markets in India. Several important points emerge from this analysis. First, unlike in a well-functioning futures market, futures prices of chickpea contracts did not converge to spot prices at the time of maturity of futures contracts. This suggests the existence of imperfections in price discovery mechanisms between futures and spot markets. This finding is in line with other studies on the functioning of agricultural commodity markets in India. In a study of various agricultural commodity markets, including for chickpea, urd bean and pigeonpea, Indian Institute of Management (2008) found that 'maturity spot and futures price often do not converge in most of the commodities and do not have any predictable pattern indicating arbitrage between cash and futures market is not likely to be strong'.

Secondly, the futures and spot markets for chickpea were found to be inefficient in assimilating information as there was a significant lead–lag relationship between the price changes in the two markets. The data suggest that there was a significant bi-directional lead–lag relationship between futures and spot prices between May 2004 and April 2008. On the other hand, in the second phase (December 2008–May 2016), the futures market led the spot market in price formation. This is consistent with the hypothesis that after December 2008, the futures market, being more leveraged than the spot market, adjusted to new information faster than the latter.

Thirdly, a GARCH model estimation of volatility found that, between December 2008 and May 2016, futures market volatility contributed to increased volatility in the spot market. It is widely agreed that speculations in commodity markets were an important factor behind the volatility of global food prices towards the end of the previous decade (De Schutter, 2010; Lilliston and Ranallo, 2011). Results from the analysis of chickpea futures markets in India are consistent with the hypothesis that speculative trade in futures markets after December 2008 may have destabilized the underlying spot market by inducing higher volatility in spot prices.

Finally, the analysis also shows that the chickpea futures market in India was not an effective instrument for hedging against price risk. This result is consistent with the existing evidence on effectiveness of agricultural futures markets in India. A committee appointed by the Department of Economic Affairs, Government of India concluded that the 'futures market is faring relatively well on price discovery and relatively poorly on hedging effectiveness' (Kolamkar *et al.*, 2014). Aggarwal, Jain and Thomas (2014), IIMB (2008) and Lokare (2007) have also found that basis risk in agricultural commodities including pulses was high.

Given that transactions in commodity exchanges were anonymous, it is not possible to precisely examine the profile of different kinds of participants using data on transactions in futures markets. However, some insights are available from studies based on primary data as well as findings of official committees on the basis of discussions with different stakeholders.

A high-level Expert Committee appointed by the Government of India has pointed out that direct participation of farmers in futures markets was low. Although participation of hedgers in the market was substantial, most of these were 'corporates, stockists, traders and cooperatives like NAFED/HAFED', and direct participation of farmers was 'negligible' (Sen *et al.*, 2008).[3] IIMB (2008) did a survey of farmers, traders and processors to study the level of awareness and nature of participation in the futures market. The survey showed that the level of awareness was very low among farmers, but substantial among traders and processors. It concluded that 'only a handful of farmers were aware of the term futures and had a very preliminary understanding of the concept'. On the other hand, all chickpea traders, 57 percent of pigeonpea traders and 80 percent of urd bean traders in the sample were found to be aware of online futures trading. Of those who were aware of online futures trading, 23 percent chickpea traders, 9 percent pigeonpea traders and 33 percent urd bean traders participated in futures trading. All of them, however, participated as speculators. Similarly, among processors, 77 percent of chickpea processors, 46 percent of pigeonpea processors and 42 percent of urd bean processors were aware of online futures trading. Most of those who participated in futures trading invested as speculators. Only in the case of urd bean, some processors reported participation as hedgers.

It is noteworthy that the total quantity of marketable surplus held by a median farmer with a median landholding of about 0.6 hectare in India is too small for participating in commodity futures as a hedger. With available futures contracts being in denominations of 1 tonne, 2 tonnes or 10 tonnes, a very small proportion of producers would have quantities by which hedging in the futures market becomes an option. Due to low levels of education, knowledge about commodity markets and computer literacy among farmers, and poor penetration of information technology in rural areas, the participation of farmers is likely to have been limited also by their inability to deal with the complexities of online futures trading. Therefore, futures markets of pulses in India are likely to have been an arena in which traders of different sizes and financial speculators dominated.

To sum up, the experience of futures markets for pulses in India suggests that, despite the pulses economy being characterized by a high level of supply risk and high level of fluctuations in retail prices, futures markets have played a limited role in providing insurance against adverse movements of prices to producers. Data from NCDEX suggest that chickpea futures were not an effective instrument for hedging against price risk, and may have contributed to increasing volatility in the spot market.

While futures markets did not provide an instrument to farmers with which to hedge their risk, and instead further contributed to the volatility of prices, they did help, albeit not without errors, traders, millers, importers and exporters in price discovery. Available evidence suggests that in the second period, futures markets were more efficient in assimilating market information, and, consequently, futures prices led prices in the spot markets. Given this, commodity futures prices are likely to have helped traders, millers, importers and exporters to anticipate market conditions.

Conclusions

Post-harvest value chains are very important in the pulses sector and have become even

3 NAFED (National Agricultural Cooperative Marketing Federation of India Limited) and HAFED (Haryana State Cooperative Supply and Marketing Federation Limited) are large national and state-level cooperatives that have been primarily active as grain procurement and storage agencies for the government.

more so with the rise in exports and imports of pulses. Value chains in the pulses sector can be categorized into three types.

In developed countries with large-scale, export-oriented production, value chains are short, and grain is procured by large exporters who mostly export it after primary processing, which involves cleaning, grading and bagging. Substantial on-farm and off-farm storage facilities exist in these countries, which makes for the countering of adverse price changes. Pulses are susceptible to storage pests, and long-term storage requires controlled temperature and humidity. Therefore, considerable losses can occur in the absence of appropriate storage infrastructure. Pulses retained (or imported) for domestic consumption in middle- and high-income countries go through canning and tertiary processing that include pulses in processed, ready-to-eat foods.

In less-developed countries with smallholder production, value chains tend to be long as small quantities of produce sold by farmers are aggregated by a long chain of intermediaries and traders. Data on prices suggest that although a considerable part of the final price paid by the consumer accrues to the producer, given the very small scale of production, the margins that accrue translate into low income levels for smallholder producers. On the other hand, increasing concentration of operations as the grain moves along the value chain implies that even with smaller unit margins, a considerable part of the total market value goes into the hands of intermediaries, traders, wholesalers and retailers.

Finally, the pulse-milling industry in South Asia has a crucial place in the value chain as the bulk of pulses are consumed after milling. About 76 percent of the world's pulse-processing capacity is located in India. There are considerable economies of scale in milling and, over the last two decades, the pulse-processing industry has seen a continuous increase in firm size. Large multinational firms now dominate the industry though small pulse-processing firms continue to exist.

India experimented with futures trading of pulses from 2004 through 2016. The statistical evidence suggests, however, that despite the high level of supply risk and price fluctuations, futures markets have played a limited role in providing insurance against adverse movement of prices to producers. Data from NCDEX, the commodity exchange where pulses futures were most traded, suggest that pulses futures may have contributed to increasing volatility in the spot markets, while they were at best an imperfect guide to spot prices in the future.

Appendix 9.1: Statistical Analysis of Futures and Spot Prices of Chickpea in India

Of the three commodity exchanges in which pulses were traded in India, chickpea futures were most liquid in the National Commodities Derivatives Exchange (NCDEX). Contracts for chickpea on NCDEX were launched for a maturity period of six months. Different contracts were available in trading units of 1 tonne, 2 tonnes and 10 tonnes. The exchange specified various quality parameters for the grain, and, for contracts that end in actual delivery, locations where the grain had to be delivered.

Detailed data on a daily basis are available from the NCDEX on prices of different futures contracts as well as prices in the spot markets. Statistical analysis of these data provides important insights on price discovery in futures markets, the effectiveness of commodity futures in mitigation of risk, and the impact of the futures market on volatility of spot prices.

Price discovery

It is expected that over the lifetime of a futures contract, as the contract proceeds towards maturity, the futures price and the spot price would converge, and finally coincide with one another at the time of maturity. Appendix Figure 9.1 presents the difference between futures price and spot price (on a logarithmic scale) on the expiry date for contracts with different expiry dates. On an average, the logarithm of futures price on the expiry date was found to be lower than that of the corresponding spot price by 1 percent. This average difference was statistically significant (at 0.05 level). The highest gap of –0.11 between the log prices of futures and spot markets was observed in the case of the futures contract that expired on 20 August 2008.

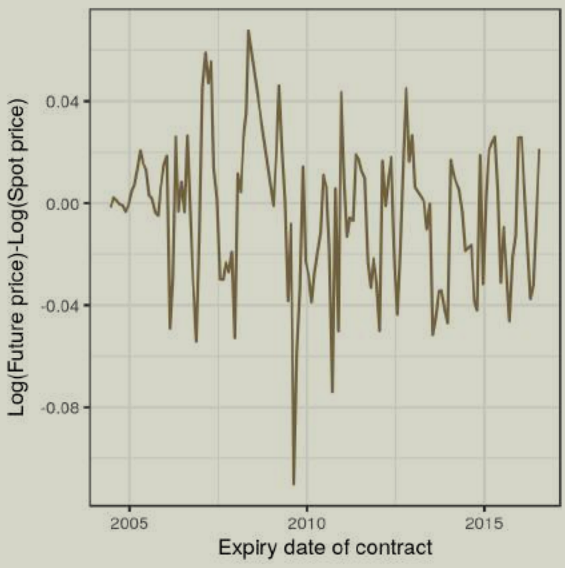
This suggests that the futures and spot prices did not converge at maturity, showing that the price discovery and price formation mechanism in the chickpea futures market was less than perfect. This finding is in line with other studies of the functioning of agricultural commodity markets in India. IIMB (2008) – one such study of various agricultural commodity markets, including for chickpea, urd bean and pigeonpea – found that 'maturity spot and futures prices often do not converge in most of the commodities and do not have any predictable pattern, indicating [that] arbitrage between cash and futures market is not likely to be strong'.

In addition to contributing towards discovery of prices, futures and spot prices at any point of time interact dynamically with one another in response to prevailing market conditions. If markets are efficient in assimilating information, then both spot and futures markets should immediately absorb the arrival of any new information in their prices, and the assimilation of information should take place simultaneously in both markets. This implies a movement in tandem of spot and futures prices, and no systematic lagged response from the movement of either price. However, if the spot and futures markets are not equally efficient in absorbing information, the market that is less efficient would lag behind the other market in assimilating information. Correspondingly, prices in the less efficient market would follow prices in the more efficient market.

Such a phenomenon can be ascertained by the existence of a lead–lag relationship in changes in futures and spot prices at contemporaneous points of time. Futures markets, being more leveraged than spot markets, are expected to respond faster to the arrival of information than spot markets. If this is the case, then futures price changes should lead spot price changes. Empirically, it has been observed that futures markets move faster than spot markets in response to the arrival of new information (Aggarwal, Jain and Thomas, 2014; Ali and Bardhan Gupta, 2011; Easwaran and Ramasundaram, 2008; Elumalai *et al.*, 2009; Inoue and Hamori, 2014; Kumar and Chaturvedula, 2013).

It may be noted that at any given point of time, there are a number of futures contracts being traded in the market, each with a different maturity date, giving rise to multiple futures prices at one point in time. Of these, the contracts due to expire in the current month (near-month contracts) are usually the most frequently traded contracts and would thus

Appendix Figure 9.1: Gap between future price on date of expiry and spot price of chickpea, NCDEX, India, 2004 to 2016



Source: NCDEX data.

Appendix Table 9.1: Results of the Vector Auto Regression (VAR) analysis of relationship between futures and spot prices of chickpea, NCDEX, India

	Period I: May 2004 – April 2008				Period II: December 2008 – May 2016			
	Coefficient	Standard error	Z	P>Z	Coefficient	Standard error	Z	P>Z
Equation for futures prices (f_t)								
f_{t-1}	–0.211	0.043	–4.87	0.00	0.014	0.042	0.33	0.74
f_{t-2}	–0.187	0.046	–3.99	0.00	0.028	0.049	0.57	0.57
s_{t-1}	0.309	0.065	4.77	0.00	0.059	0.064	0.93	0.35
s_{t-2}	0.091	0.051	1.78	0.08	0.107	0.066	1.63	0.10
Constant	0.025	0.064	0.39	0.70	0.047	0.055	0.85	0.40
Equation for spot prices (s_t)								
f_{t-1}	0.391	0.027	14.73	0.00	0.418	0.032	13.1	0.00
f_{t-2}	–0.052	0.029	–1.81	0.70	-0.056	0.037	–1.49	0.14
s_{t-1}	–0.025	0.039	–0.65	0.52	0.014	0.488	0.29	0.77
s_{t-2}	0.004	0.031	0.02	0.99	0.074	0.05	1.5	0.13
Constant	0.057	0.039	1.48	0.14	0.004	0.042	0.08	0.93

Note: This VAR analysis models futures price change at time t (f_t) and spot price change at time t (s_t) as linear functions of their own lagged values and lagged values of the other price. The significance of the parameters of the estimated VAR model indicates whether past values of any one variable influences the present value of the other, thus establishing if there is any lead–lag relationship.
Source: Daily data on futures and spot prices, NCDEX.

reflect the maximum information. Accordingly, in order to examine the dynamic interplay of spot and futures markets, spot prices were compared with a futures price-series of near-month contracts, with a rollover to the next contract two days prior to the expiry of the current contract. In view of the fact that futures trade in pulses was briefly suspended between July and December 2008, data were analysed separately for May 2004 to April 2008, and January 2009 to May 2016.

The VAR (vector auto regression) estimation results presented in Appendix Table 9.1 show that in the first period (May 2004 to April 2008), the futures and spot markets display a degree of a bi-directional relationship. This is evident from the significant coefficient of s_{t-1} in the equation for futures prices and of f_{t-1} in the equation for spot prices. During this period, lagged values of futures prices influenced present values of spot prices and vice versa. In the second period (December 2008 to May 2016), however, there was a uni-directional relationship from futures to spot market for chickpea. Thus, in the more recent period, the futures market seemed to respond to new information faster than the spot market and thus the lagged values in futures price changes influenced spot price changes. This is consistent with the hypothesis that futures markets, being more leveraged than spot markets, adjust faster to new information. The futures and spot markets for chickpea were found to be inefficient in assimilating information as there were significant lead–lag relationships between the price changes in the two markets. In the second period, the futures market led the spot market in price formation.

Impact of futures market on volatility

Notwithstanding a considerable amount of debate that took place at the time, it is now widely agreed that speculations in commodity markets were an important factor accounting for the volatility of food prices towards the end of the previous decade (De Schutter, 2010; Lilliston and Ranallo, 2011). While futures contracts provide producers a facility to hedge against unfavourable price movements, like any other financial asset, these are also tools for speculative trading and arbitrage opportunities. Speculative traders and arbitragers are investors who indulge in trading in futures and spot markets to reap financial gains from daily price movements, and are not interested in the ultimate physical delivery of the products. Thus, futures markets have three types of

Appendix Table 9.2: Results of the Vector Auto Regression (VAR) analysis of volatility spill-over between futures and spot price changes of chickpea, NCDEX, India

	Period I: May 2004 – April 2008				Period II: December 2008 – May 2016			
	Coefficient	Standard error	Z	P>Z	Coefficient	Standard error	Z	P>Z
Equation for variance of change in futures prices (vf_t)								
vf_{t-1}	1.102	0.039	28.15	0.00	2.130	0.087	24.56	0.000
vf_{t-2}	–0.004	0.054	–0.07	0.94	–0.580	0.177	–3.27	0.001
vs_{t-1}	0.090	0.040	2.4	0.02	0.014	0.015	0.93	0.354
vs_{t-2}	–0.032	0.050	0.68	0.50	-0.028	0.236	–1.19	0.233
Constant	–0.321	0.037	–8.02	0.00	-2.368	0.236	–10.04	0.000
Equation for variance of change in spot prices (vs_t)								
vf_{t-1}	0.240	0.033	7.09	0.00	0.649	0.256	2.53	0.010
vf_{t-2}	–0.197	0.046	–4.24	0.00	–1.220	0.522	–2.34	0.020
vs_{t-1}	0.937	0.032	29.01	0.00	1.050	0.045	23.40	0.000
vs_{t-2}	0.042	0.041	1.03	0.30	–0.220	0.070	–3.2	0.001
Constant	–0.191	0.032	–6.03	0.00	0.938	0.696	1.35	0.178

Note: This VAR analysis models log variance of change in futures price at time t (vf_t) and log variance of change in spot price at time t (vs_t) as linear functions of their own lagged values and lagged values of the other variable. The significance of the parameters of the estimated VAR model indicates whether past values of any one variable influences the present value of the other, thus establishing if there is any lead–lag relationship.
Source: Daily data on futures and spot prices, NCDEX.

agents: hedgers (who use futures markets to hedge against adverse price movements at the time of physical delivery of their product), speculators (who use futures markets to reap financial gain from price fluctuations) and arbitragers (who make financial gain by taking advantage of any misalignment of prices in futures and spot markets). The presence of different kinds of market participants induces a high level of integration and dynamic interaction between spot and futures markets. Any arrival of news or speculation could affect the markets in such a way that tremendous volatility is created in the movements of prices in both markets. Increased price volatility may defeat the purpose of risk management allowed in futures markets. Therefore, the ultimate (long-term) benefits of futures markets, particularly in agricultural commodities, are mixed.

Due to information assimilation and speculation, futures markets are also expected to have higher volatility than spot markets. This is due to the fact that futures markets are supposed to take speculative activities away from spot markets. However, due to continuous interaction between the two markets, volatility from the futures market may spill over to the spot market, and, as a result, spot price volatility may increase. Increased interaction between spot and futures markets may not always be effective in terms of risk management. The effectiveness of a futures market depends on how volatile the difference between futures and spot prices are. A futures market is considered effective for hedging if the variance of the difference between the spot price and the futures price (St–Ft) is less than the variance of the underlying spot price (St).

The daily volatility in price movements of the two markets can be estimated by using a generalized autoregressive conditional heteroscedasticity (GARCH) model. These volatility estimates can then be used to examine how the volatility in futures and spot markets interact with one another. We used a GARCH (1,1) model to estimate day-to-day volatility in returns (changes) of futures and spot prices of chickpea in NCDEX for the period under consideration. Then, a VAR model was estimated using the logarithm of these daily volatility measures.

Appendix Table 9.2 presents the results of this VAR estimation. As seen from the table, during the first period, there was significant bi-directional volatility spill-over between the two markets, as evident from the significance of some of the lagged coefficients in determining the variance of the other market. For example, volatility in the futures market was significantly affected by one-period lagged volatility in the spot market, and, similarly,

Appendix Table 9.3: Variance ratio test for spot price and basis (difference between the spot and the futures prices) for chickpea, NCDEX, India

Change in	Mean	Standard deviation	F	p-value
May 2004 – April 2008 (1150 observations)				
Spot prices	0.061	1.397	863.9	0.000
Basis	–24.52	1206.5		
December 2008 – May 2016 (2089 observations)				
Spot prices	0.059	1.349	497.3	0.000
Basis	–13.78	670.9		

Source: Daily data on futures and spot prices, NCDEX.

volatility in the spot market was also significantly influenced by past futures market volatility (both at lag one and lag two). In the second period, however, there was a uni-directional volatility spill-over from the futures market to the spot market. Results for this period show that the parameters for lagged volatility in the futures market affected volatility in both the futures and spot markets significantly, while lagged volatility in the spot market affected the volatility of only the spot market. This implies that volatility spill-over in the later period was from futures market to spot market and not vice versa. Thus, in the case of the chickpea futures market in the recent period, it is observed that volatility in the futures market increased volatility in the spot market. This indicates that the speculative trade associated with futures markets could have destabilized the underlying spot market by inducing higher volatility in spot prices.

Effectiveness of chickpea futures market for hedging risk

It is argued that futures contracts provide a means to hedge against unfavourable price movements, as prices for a future transaction are fixed beforehand. A futures market is effective for hedging price risk if the difference between spot and futures prices (St–Ft), also called the basis, is not very volatile. If the variance of the basis is less than the variance of spot prices, then a futures market can be considered effective for hedging. Appendix Table 9.3 presents the results of a variance ratio test for the hypothesis that the variance of the basis is less than that of the spot price. The results show that during both periods, the variance of the basis was significantly higher than the variance of the spot price changes. This suggests that the chickpea futures market was not an effective place for farmers to hedge against price risk.

These results are broadly consistent with existing evidence on the effectiveness of agricultural futures markets in India. A committee appointed by the Department of Economic Affairs, Government of India, concluded that the 'futures market is faring relatively well on price discovery and relatively poorly on hedging effectiveness' (Kolamkar *et al.*, 2014). Aggarwal, Jain and Thomas (2014), IIMB (2008) and Lokare (2007) have also found that the basis risk in agricultural commodities, including pulses, was high.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DRIVERS OF GROWTH AND FUTURE GROWTH PROSPECTS

Vikas Rawal, with contributions from Merritt Cluff

There has been significant acceleration in the rate of growth of pulse production and trade over the last fifteen years. This chapter discusses the main factors that have contributed to and facilitated this growth, and examines the prospects for future growth.

The projections for future growth presented here were made using a partial equilibrium economic model that included the domestic markets of 162 countries in terms of production, consumption (food, feed, other use) and trade (exports/imports). The model was designed using a template similar to those defined in the Aglink Cosimo model (OECD–FAO, 2015). Production was determined dynamically as crop prices deflated by input costs drive both area allocation and yield. Consumption of pulses as food and feed, and use of pulses for other purposes, were assumed to be driven by incomes, population, and estimated consumer prices of own and competing products. Trade was assumed to be determined by domestic prices relative to international market prices, adjusted for exchange and transaction costs.

The parameters of the model were chosen using informed, *a priori* judgement, with average values lying within a defined range and country-specific values within a range determined by the degree of development. Own-area response elasticities (using returns per hectare) were assumed to range from 0.12 for developing countries to about 0.5 for developed countries. Food use elasticities ranged from about −0.6 (for developing countries) to −0.25 (for developed countries). Export and import elasticities were fixed at −4 for developed countries and 4 for developing countries. Trend factors were included in many equations; these were estimated over the historical period, generally from 1990 to 2014. Adjustments were made for country-specific conditions, in particular for India, Canada, the European Union and the United States, as well as for Nigeria and Myanmar.

Data for the pulses sector were taken from the FAOSTAT database. However, these data required some simple adjustments to square off the base period for projection, which is considered to be 2013–15. Data on key macro variables such as GDP, the GDP deflator, exchange rate and population were taken from the IMF's *World Economic Outlook* of 2015 and the UN Population Division.

Growth of Production and Trade

Between 2001 and 2014, global production of pulses increased by over 20 million tonnes. This increase was mainly on account of an increase in the production of common bean, chickpea, cowpea and lentil. Over this period, annual production of dry beans went up by about 7 million tonnes, annual production of chickpea by about 5 million tonnes, annual production of cowpea by about 3.8 million tonnes and annual production of lentil by about 1.6 million tonnes.

This growth in pulse production originated primarily in sub-Saharan Africa, North America, Australia, India and Myanmar. India is the world's largest producer of pulses as well as the world's biggest market for pulses. After several decades of stagnation, there was accelerated growth of production of pulses, due to a transformation in the conditions of chickpea production in the country. Between 2001 and 2014, about 4 million hectares of land in India were brought under chickpea production.

During these years, there has been a significant increase in the production of cowpea and common bean in sub-Saharan Africa. Inclusion of pulses in the crop rotation cycle emerged as an attractive scenario for large farms in parts of North America and Australia as well, over this period. While Australian farms produce chickpea and mung bean, Canadian farmers have incorporated lentil and dry pea into their cropping cycles. In the United States, bean production is widespread in the northern region.

Myanmar, with a predominance of small farms producing mainly chickpea, pigeonpea, mung bean and urd bean, has also emerged as a major export-oriented producer of pulses.

Prices, Cost of Production and Margins

Returns from cultivating pulses vary a great deal across different countries, across agroclimatic regions within countries, between different pulse crops and across different farm-types. In this report, data from nationally representative surveys, sub-national surveys and, in a few instances, micro-level surveys have been used to examine differences in gross margins across regions and farming types for each major pulse crop. Although gross margins do not take into account the cost of fixed capital and despite the fact that data from different countries are not based on uniform estimation methodologies, significant differences that show up are broadly indicative of the pattern of variations in returns from pulse cultivation.

In chapters 3 to 8 of this report, data on gross margins were compared to examine variations in returns across different countries and farming types. The analysis – based on gross margins computed in terms of kilograms of pulse grain per hectare, to account for variations in prices and exchange rates – showed that there is considerable variation in gross margins across countries, in particular between large, industrial-scale farms on the one hand and smallholder production on the other. The data showed that the higher margins that accrue in large-scale farming are primarily on account of higher yield and lower costs as compared to smallholder production.

Large, industrial-scale farms in developed countries like Canada and Australia benefit from economies of scale, particularly in the deployment of machines, and higher use of improved varieties of seeds, inoculants and plant protection chemicals. In contrast, smallholder production is often characterized by low levels of adoption of improved technology, and high costs of human and machine labour deployed for land preparation, plant protection and harvesting. With poorly developed farm infrastructure and low levels of scientific knowledge, smallholder production of pulses is affected by considerable biotic and abiotic stresses, and is therefore characterized by a high degree of uncertainty. Table 10.1 presents a summary of the data on gross margins earned from cultivation of pulse crops. These data, although subject to exchange-rate variations, show the divide between countries where pulse production takes place in industrialized farms and countries where pulses

Table 10.1 Average per hectare gross margin in production of pulses, major producing countries, 2007–15 (USD per hectare)

Country, Year	Chickpea	Red lentil	Mung bean	Common bean	Urd bean
India, 2013–14	204	264	109		68
Bangladesh, 2011		142			
Myanmar, 2016	139		468		248
Australia, 2015	294	369	542		
Turkey, 2009	379				
Saskatchewan, Canada, 2016		919			
United States (southeast, North Dakota), 2015				174	
Brazil (large-scale farms), 2015				220	
Mexico, 2015–16				309	
Kenya, 2010–13				303	
Uganda, 2012				147	

Source: Data on gross margins in local currency units from CACP (2015) for India; Rahman *et al.* (2013) for Bangladesh; Zorya *et al.* (2016) for Myanmar; Government of South Australia (2015); Ørum *et al.* (2009) for Turkey; Government of Saskatchewan (2016); North Dakota State University for the United States; CONAB for Brazil; AARFS A.C. for Mexico; Fintrac Inc. (2013) for Kenya; and Kilimo Trust (2012) for Uganda. Exchange rate data from International Financial Statistics, IMF.

are mainly produced by smallholder producers. The table shows that the margins in South Asia, Myanmar and sub-Saharan Africa, countries with a predominance of pulse production on smallholder farms, are lower than in Canada and Australia, where production takes place on large, industrial-scale farms. Among all the countries for which data were available, lentil production in Canada had the highest per hectare margin (USD 919 per hectare), while urd bean production in India had the lowest gross margin (USD 68 per hectare).

But how do returns from cultivation of pulses compare with returns from cultivation of other, competing crops? The answer to this question contains some important insights into the recent acceleration in the rate of growth of pulse production. Table 10.2 shows the ratio of gross margins from pulse cultivation to gross margins from cultivation of competing crops in selected countries. Although such data are available only for a few pulse-producing countries, the large variations seen across countries and crops are noteworthy. Pulses have lower yields than major competing crops like wheat. However, the yield disadvantage is considerably reduced with higher adoption of technology and economies of scale on large-scale farms. With a reduced yield disadvantage and a substantial price advantage, pulse production on large farms in Canada, Australia and Brazil is more remunerative than the production of major competing crops. Gross margins in lentil production in Canada were estimated to be 1.8 times the margins in wheat, 1.7 times the margins in canola and 3.6 times the margins in soybean. Returns from dry pea production were estimated to be twice the returns from soybean, and roughly equal to the returns from wheat and canola. In Australia, gross margins in lentil cultivation were about the same as margins in wheat, while gross margins in chickpea cultivation were estimated to be slightly lower. In contrast, gross margins in mung bean were only 37 percent of the margins in paddy, and margins in urd bean were only 43 percent of margins in paddy. Among the cool season legumes, returns from chickpea were 55 percent of returns from wheat, while returns from lentil were only 56 percent of returns from wheat.

Data showing higher gross margins in pulse production on Australian and Canadian large-scale farms are consistent with increasing adoption of pulse production by commercial farmers. Pulse farming has become an integral part of the cropping cycle in these countries. The high returns from pulse production, and the positive effect, because of nitrogen fixation in the soil, of pulse cultivation on other crops produced in subsequent years, have made the inclusion of pulse crops in the cropping cycle a compelling proposition for farmers.

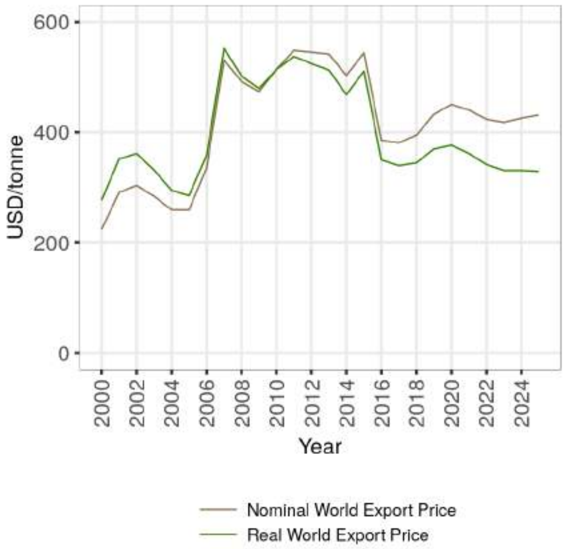
However, a substantial part of the growth in pulse production is also accounted for by smallholder farms in developing countries like India. On smallholder farms, pulses are often intercropped, mix-cropped or sequentially cropped with other crops in the same year. It is common to intercrop a pulse crop with another crop of different duration, so that one crop is harvested before the other grows to its full size. In such cases, both the intercrops can be planted with almost the same density as that of sole crops. In cases where pulses are intercropped or mix-cropped, the returns from the land cultivated in a particular crop season are more than the returns from just pulses. In conditions where resources like land and water are in short supply, family farmers may take economic decisions not merely on the basis of returns over capital or returns per hectare from a single crop, but on the basis of overall income as well as consumption requirements. With the development of short-duration varieties of many pulses, incorporation of a pulse crop as an additional crop on smallholder farms with limited irrigation facilities has become economically advantageous. On irrigated farms, on the other hand, although crops like wheat and rice are often more profitable, growing pulses as additional crops in the dry season, when irrigation facilities are limited, raises farm incomes. Consequently, even though pulses are less profitable as compared to irrigated crops like wheat and rice, cultivation of pulse crops

Table 10.2 Ratio of gross margins in pulse production to gross margins in competing crops

	Australia (2015)	Canada (2016)	India (2013–14)	Turkey (2009)	Brazil (large farms, 2016)
Chickpea : Wheat	0.86		0.55	0.79	
Lentil : Wheat	1.09	1.81	0.56		
Lentil : Canola		1.68			
Lentil : Soybean		3.63			
Dry pea : Wheat		1.04			
Dry pea : Canola		0.96			
Dry pea : Soybean		2.08			
Urd bean : Paddy			0.43		
Mung bean : Paddy			0.37		
Common bean : Corn					1.62–2.10
Common bean : Soybean					2.00–5.20

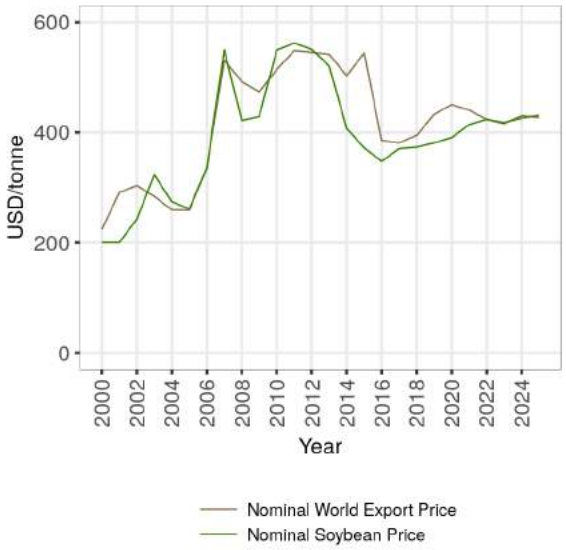
Source: Data on gross margins from SAGIT, GRDC, and Government of South Australia (2015) for Australia; Saskatchewan (2016) for Canada; CACP (2015) for India; Ørum *et al.* (2009) for Turkey; and CONAB for Brazil.

Figure 10.1: International prices of pulses, trends (2000–14) and projections (2015–24)



Note: Pulse prices here refer to unit value of Canadian exports of pulses.
Source: Cluff (2016).

Figure 10.2: International prices of pulses and soybean, trends (2000–14) and projections (2015–24)



Note: Pulse prices here refer to unit value of Canadian exports of pulses.
Source: Cluff (2016).

in unirrigated fields and in dry seasons has the potential of significantly augmenting the incomes of even smallholder producers. It is thus increasingly seen as an attractive proposition by smallholder producers in many countries.

Over the last ten years, the international prices of pulses, as represented by the unit value of Canadian pulse exports, have registered a strong upward trend, in tandem with the price-trend of crops like oilseeds. However, unlike oilseed prices, the prices of pulses remained relatively high even in 2015–16, due to a strong import demand from India, where there was a large shortfall in production because of drought (see Figures 10.1 and 10.2). If history is a guide, it is reasonable to expect that pulse prices in 2016 may fall considerably from the cyclical highs, to settle back into their close relationship with oilseed prices (Figure 10.2). This, in turn, will reduce the incentive for expansion of global pulse production as witnessed in the past decade, particularly in countries where pulses are grown for exports.

Growth in Demand for Pulses in the Future

Food consumption trends are key long-term drivers of commodity demand. Over the last three decades, global consumption of pulses has remained stagnant at about 21 grams per capita per day. Aggregate consumption of pulses has risen mainly on account of population growth in the Indian subcontinent, a rise in per capita consumption of pulses in sub-Saharan Africa, and an increase in the use of pulses as feed in the developed countries of Europe and North America. Over this period, there has also been a growing preference for animal-based proteins. As discussed in chapter 2, this has been fuelled by an increase in relative retail prices of pulses vis-á-vis animal-based foods as well as consumer preference for foods of animal origin.

Projections for growth in consumption of pulses presented in Table 10.3 show that, out of about 21 million tonnes of projected increase in annual consumption between 2013–15 and 2025, about 10 million tonnes are expected to be located in Asia and about 7 million tonnes in sub-Saharan Africa. It is noteworthy that about a quarter of the projected increase is expected to be located in India alone.

As shown in Table 10.4, 68 percent of this global increase in consumption of pulses will be in the form of food, 13 percent in the form of animal feed, and the rest for other uses (which

Table 10.3 Projected growth in total consumption of pulses, 2013–15 to 2025 (million tonnes and percent)

	Consumption		Projected consumption	Increase	Growth rate (percent)	
	2003–05	2013–15	2025	2013–25	2006–15	2016–25
North America	2.3	2.7	3.2	0.6	1.5	1.2
Canada	1.1	1.3	1.8	0.4	3.6	1.6
United States	1.2	1.3	1.5	0.1	–0.4	0.7
Latin America and the Caribbean	6.9	7.8	9.5	1.7	1.2	1.2
Argentina	0.1	0.1	0.1	0.0	–6.3	1.5
Brazil	3.2	3.6	4.2	0.6	0.5	0.6
Mexico	1.5	1.7	2.0	0.3	1.4	1.0
Sub-Saharan Africa	10.8	15.6	22.4	6.8	3.6	3.1
Ethiopia	1.2	2.0	3.1	1.0	4.8	3.9
Kenya	0.6	0.9	1.3	0.4	4.1	2.5
Nigeria	2.7	3.5	4.3	0.8	2.6	3.2
Tanzania	0.9	1.3	2.2	0.9	3.5	3.2
North Africa and Middle East	2.8	3.5	4.6	1.1	3.6	2.3
Europe	5.8	3.9	3.9	0.0	–1.9	–0.6
European Union	5.7	3.8	3.7	–0.1	–2.2	–0.7
Eastern Europe and Central Asia	4.2	4.3	5.2	0.9	2.1	0.9
Russia	1.7	2.0	2.3	0.3	4.1	0.9
Turkey	1.3	1.4	1.7	0.3	1.9	1.1
Asia	26.2	36.1	45.9	9.8	3.6	1.7
China	4.5	4.8	5.6	0.9	2.3	0.7
India	15.3	22.1	27.2	5.1	3.7	1.3
Myanmar	1.9	3.8	5.9	2.1	5.9	4.2
Pakistan	1.3	1.5	1.8	0.3	1.5	1.3
Oceania	1.5	1.3	1.5	0.2	6.9	0.4
Australia	1.4	1.3	1.4	0.1	7.0	0.4
World	60.5	75.5	96.5	21	2.8	1.8

Source: Cluff (2016).

Table 10.4 Projected increase in annual consumption of pulses for food, feed and other purposes, 2016 to 2025 (million tonnes)

Region/Country	Food	Feed	Other uses	Total
North America	0.2	0.2	0.2	0.6
Canada	0.1	0.1	0.2	0.4
United States	0.1	0.0	0.0	0.1
Latin America and the Caribbean	1.6	0.0	0.1	1.7
Argentina	0.0	0.0	0.0	0.0
Brazil	0.6	0.0	0.0	0.6
Mexico	0.3	0.0	0.0	0.3
Sub-Saharan Africa	5.7	0.2	0.9	6.8
Ethiopia	0.9	0.0	0.1	1.0
Kenya	0.4	0.0	0.0	0.4
Nigeria	0.8	0.1	0.0	0.8
Tanzania	0.7	0.0	0.1	0.9
North Africa and Middle East	1.0	0.1	0.1	1.1
Europe	0.1	–0.1	0.0	0.0
European Union	0.1	–0.1	0.0	–0.1
Eastern Europe and Central Asia	0.4	0.2	0.2	0.9
Russia	0.1	0.0	0.2	0.3
Turkey	0.3	0.0	0.0	0.3
Asia	5.1	2.2	2.5	9.8
China	0.4	0.4	0.1	0.9
India	2.6	0.4	2.1	5.1
Myanmar	0.6	1.3	0.2	2.1
Pakistan	0.3	0.1	0.0	0.3
Oceania	0.1	0.1	0.0	0.2
Australia	0.0	0.1	0.0	0.1
World	14.2	2.8	3.9	21.0

Source: Cluff (2016).

mainly includes use as seed). Of 14.2 million tonnes of annual increase in food consumption, 5.7 million tonnes are projected to be in sub-Saharan Africa and 5.1 million tonnes in Asia. India's consumption of pulses as food is projected to increase by 2.6 million tonnes per year by 2025.

In most regions of the world, use of pulses in animal feed has plateaued because of availability of cheaper plant protein from soybean. The only country for which the model projects substantial growth in use of pulses as feed is Myanmar, where pulses are mainly produced for export to India but are used for feed in years when the export demand declines. Fluctuating export demand from India, however, is also likely to work as a general depressor for growth of pulse production in Myanmar in the future.

These projections for growth of consumption are based on the assumption that global prices of pulses will fall back to their long-term trend, and that global efforts to reduce protein malnutrition will pick up pace. Protein gaps are more pronounced than calorie gaps in the developing countries, and an increase in the consumption of food items like pulses that are rich in protein is imperative for meeting global targets on malnutrition.

Medium-term Projections for Production and Trade

Table 10.5 presents the results of the model for production of pulses. The model predicts that the global growth rate of pulse production between 2016 and 2025 will be about 1.8 percent per year. Of the total increase of 18 million tonnes in global annual production of pulses, the model predicts that about 5 million tonnes will take place in India, 4 million tonnes in sub-Saharan Africa, 3 million tonnes in Canada, 3 million tonnes in Myanmar, and 1 million tonnes each in Australia, Brazil and Russia.

The global pulse trade has grown rapidly, rising from 13 percent of production in 2003–05 to almost 18 percent in recent years. Exports grew at a rate of 4.3 percent per year in the last decade but are projected to slow down over the next decade, growing at a rate of only 1.6 percent per year, as it is anticipated that production growth in key importing countries will meet the growth of domestic markets (Table 10.6). India dominates the international import market for pulses with a market share of around 30 percent, followed by a number of large importers such as China, the European Union, Bangladesh and Pakistan. The model projects that pulse production in India will grow and that the country's reliance on imports will decline. China imports pulses for use as animal feed as well as for human consumption. The model projects a slowdown in the growth of consumption for both these uses in China. Consequently, the growth of pulse imports of China will fall from about 18 percent per year in the last decade to less than 1 percent per year in the next decade.

Policy Support for Future Growth

The growth of pulse production over the last decade-and-a-half has been a result of concerted public action towards developing improved varieties and identifying suitable agronomic varieties, to make cultivation of pulses attractive for farmers in diverse agroclimatic regions and economic contexts across the world. The growth was witnessed not only in countries that diversified into pulse production to meet export demand, but also in countries where smallholder production expanded to meet domestic demand. While high prices provided an impetus to exporting countries and at least partly mitigated the yield disadvantage for smallholder producers, in all countries that registered a growth in pulse production, it was a result of sustained efforts of the scientific community and public initiatives to take improved technologies to the farmers.

In view of the prospect of a decline in the international prices of pulses, achieving an annual growth rate in pulse production of even 1.8 percent over the coming decade will require increased support to smallholder producers, as well as increased investment in research and extension activities.

Increased support to smallholder producers

Pulse production on smallholder farms is characterized by low yields and high risk. Given the low and uncertain returns from pulses, most of smallholder production takes place on marginal soils, on land without irrigation facilities and with little access to technological improvements. Smallholder producers of pulses in developing countries lack access to improved varieties of seeds, knowledge about appropriate agronomic practices to deal with biotic and abiotic stresses, and resources for buying inputs. Consequently, yield gaps on smallholder farms are high.

Support to smallholder pulse production in the form of public extension services, provision

Table 10.5 Projections for annual production of pulses, by country and region, 2016 to 2025 (million tonnes and percent)

	Production		Projected production	Increase	Growth rate (percent)	
	2003–05	2013–15	2025	2013–25	2006–15	2016–25
North America	5.6	8.3	11.3	3.0	3.7	2.2
Canada	3.9	6.0	8.7	2.7	4.4	2.8
United States	1.7	2.4	2.6	0.3	2.1	0.6
Latin America and the Caribbean	6.2	7.0	8.3	1.3	0.4	1.0
Argentina	0.2	0.3	0.4	0.1	–3.2	0.0
Brazil	3.1	3.2	3.8	0.6	–1.1	1.0
Mexico	1.4	1.6	1.7	0.1	1.1	0.1
Sub-Saharan Africa	10.2	17.6	21.8	4.2	5.5	2.6
Ethiopia	1.2	2.7	3.2	0.5	8.2	2.8
Kenya	0.5	1.1	1.3	0.2	8.4	2.4
Nigeria	2.7	3.5	4.3	0.8	1.7	3.2
Tanzania	0.9	1.9	2.5	0.6	7.2	2.6
North Africa and Middle East	1.9	1.9	2.4	0.5	1.8	2.0
Europe	5.0	3.3	3.1	–0.2	–0.3	–0.9
European Union	5.0	3.3	3.1	–0.2	–0.3	–0.9
Eastern Europe and Central Asia	4.7	4.6	5.5	0.9	2.0	1.2
Russia	1.7	2.3	3.2	0.9	5.7	2.1
Turkey	1.6	1.1	1.3	0.1	–2.3	0.6
Asia	25.1	31.4	39.2	7.8	2.5	1.7
China	5.3	4.5	4.9	0.5	–0.2	0.5
India	13.8	18.8	23.5	4.7	3.5	1.7
Myanmar	2.8	5.0	7.7	2.6	3.4	3.4
Pakistan	1.1	1.0	0.9	–0.2	0.0	0.1
Oceania	2.2	3.0	3.8	0.7	12.5	1.3
Australia	2.2	3.0	3.7	0.7	12.7	1.3
World	61.0	77.5	95.9	18.4	3.2	1.8

Source: Cluff (2016).

Table 10.6 Projections for annual exports of pulses, by country and region, 2016 to 2025
(million tonnes and percent)

	Actual export		Projected export	Increase	Growth rate (percent)	
	2003–05	2013–15	2025	2013–15	2006–15	2016–25
North America	3.1	6.4	8.5	2.1	4.6	2.5
Canada	2.5	5.1	7.0	1.9	5.1	3.0
United States	0.6	1.2	1.5	0.2	2.9	0.2
Latin America and the Caribbean	0.5	0.6	0.5	0.0	–0.2	–1.3
Argentina	0.2	0.2	0.3	0.1	–2.7	–0.3
Brazil	0.0	0.0	0.0	0.0	21.3	2.2
Mexico	0.1	0.2	0.1	–0.1	1.8	–4.2
Sub-Saharan Africa	0.2	0.9	0.7	–0.1	14.1	–2.8
Ethiopia	0.1	0.4	0.2	–0.2	12.9	–5.9
Kenya	0.0	0.1	0.1	0.0	29.0	–0.9
Nigeria	0.0	0.0	0.0	0.0	28.3	4.5
Tanzania	0.1	0.2	0.3	0.1	15.4	–1.3
North Africa and Middle East	0.3	0.3	0.2	–0.1	1.3	–1.4
Europe	0.5	0.5	0.5	0.0	0.3	–0.2
European Union	0.5	0.5	0.5	0.0	0.3	–0.2
Eastern Europe and Central Asia	0.6	0.9	1.1	0.2	8.5	3.8
Russia	0.1	0.5	0.9	0.3	31.8	5.7
Turkey	0.3	0.2	0.1	–0.1	–2.8	–1.6
Asia	2.3	2.8	3.0	0.2	0.6	0.4
China	0.9	0.9	0.6	–0.3	–0.5	–0.9
India	0.3	0.4	0.6	0.1	11.8	0.5
Myanmar	0.9	1.4	1.7	0.3	0.1	0.9
Pakistan	0.1	0.0	0.0	0.0	–15.0	0.0
Oceania	0.6	1.5	2.3	0.9	11.4	1.9
Australia	0.6	1.5	2.3	0.9	11.5	2.0
World	8.1	13.9	17.1	3.3	4.3	1.6

Source: Cluff (2016).

Table 10.7 Projections for annual imports of pulses, by country and region, 2016 to 2025 (million tonnes and percent)

	Import		Projected import	Increase	Growth rates (percent)	
	2003–05	2013–15	2025	2013–25	2006–15	2016–25
North America	0.3	0.5	0.4	–0.1	4.2	–0.9
Canada	0.1	0.1	0.1	0.0	2.3	–2.9
United States	0.3	0.4	0.3	–0.1	4.9	–0.2
Latin America and the Caribbean	1.0	1.2	1.8	0.5	1.6	1.0
Argentina	0.0	0.0	0.0	0.0	–2.4	0.3
Brazil	0.1	0.4	0.4	0.0	14.7	–2.1
Mexico	0.1	0.2	0.4	0.2	3.6	4.4
Sub-Saharan Africa	0.5	0.6	1.4	0.8	–1.2	6.1
Ethiopia	0.0	0.1	0.1	0.0	2.6	6.2
Kenya	0.0	0.1	0.1	0.0	–0.9	0.9
Nigeria	0.0	0.0	0.0	0.0	–16.0	0.0
Tanzania	0.0	0.0	0.0	0.0	–5.4	1.3
North Africa and Middle East	1.2	1.7	2.4	0.7	2.4	2.3
Europe	1.7	1.1	1.3	0.1	–2.8	0.5
European Union	1.6	1.0	1.1	0.1	–3.3	0.2
Eastern Europe and Central Asia	0.1	0.4	0.7	0.3	10.1	2.2
Russia	0.0	0.0	0.0	0.0	–1.1	–5.4
Turkey	0.1	0.3	0.5	0.2	14.3	1.6
Asia	3.4	8.2	9.6	1.4	8.2	1.1
China	0.1	1.1	1.3	0.1	18.3	0.9
India	1.8	4.7	4.3	–0.4	8.1	–0.5
Myanmar	0.0	0.0	0.0	0.0	0.0	0.0
Pakistan	0.3	0.4	1.0	0.5	0.9	2.6
Oceania	0.0	0.0	0.0	0.0	3.7	1.3
Australia	0.0	0.0	0.0	0.0	0.8	–1.9
World	8.3	13.9	17.7	3.8	4.7	1.5

Source: Cluff (2016).

of improved technologies and inputs, and availability of credit and insurance facilities can go a long way towards closing yield gaps on smallholder farms.

Pulses have a crucial place in sustainable intensification of crop production. Through nitrogen fixation in the soil, they displace the use of fossil fuel-based nitrogen fertilizers. Expansion of pulse production, therefore, can play a vital role in mitigating the effects of climate change. However, due to their high protein content, pulse crops have an inherent yield disadvantage over foodgrain crops. Although considerable improvement can be achieved in the yields of pulses with greater adoption of improved varieties and scientific agronomic practices, high prices have been a crucial determinant in the past decade for the remunerativeness of pulse production even in countries with high yield levels. In countries marked by smallholder production, pulse crops remain unremunerative in comparison with other competing crops. Low levels of per hectare margins act as a double disadvantage for smallholder producers of pulses: given the small sizes of their farms, low per hectare margins result in abysmal levels of per worker and per farm incomes.

In view of the projected decline in prices of pulses, it is important to consider ways of compensating pulse producers for the ecological service they render by cultivating pulses as well as their contribution to human nutrition. This can potentially be a basis for extending support to smallholder producers for their contribution to sustainable food production.

Increased investment in research and extension

Concerted efforts of agricultural scientists and breeders under the aegis of CGIAR institutions and national agricultural research systems have played a critical role in facilitating the growth of pulse production over the last fifteen years. Research on pulses under CGIAR is led by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Center for Agriculture Research in the Dry Areas (ICARDA) and the International Center for Tropical Agriculture (CIAT). Work done over decades at these institutions is the foundation on which most national pulse-breeding programmes have been built. As detailed in Box 10.1, various international and national research institutions are involved in the collection and preservation of genetic resources for pulses.

Most pulses are self-pollinating crops. This affects the breeding of pulses in different ways, and makes the breeding of improved varieties more difficult, resource-intensive and time-consuming. First, genetic diversity within a pulse species is more limited than, say, for cereal crops. Varietal development for higher yields, disease resistance and quality of seed through conventional breeding is constrained by the lack of several desired traits (such as resistance to particular pests) within the gene pool of the crop and its wild relatives. Secondly, since the probability of successful cross-pollination of these crops is lower, conventional breeding for self-pollinated crops is more difficult and takes more time. Thirdly, also because of low levels of cross-pollination, commercial production of hybrids is not possible for most pulse crops. This has historically acted as a disincentive for private sector investment in pulse research and production of pulse seeds.

Pulses are highly susceptible to diseases and pests, and compete poorly with weeds. A large part of pulse production happens on marginal soils and in rainfed conditions. Although pulses are extremely resilient crops, cultivation of pulse crops in harsh environments suffers from abiotic stresses such as drought, flooding, salinity, frosting and extreme temperatures.

Pulses are leguminous crops and their cropping helps fix nitrogen in the soil, thus serving as a substitute for fossil fuel-based nitrogenous fertilizers. Pulses are highly nutritious with high content of protein, minerals and micronutrients, and, given their low levels of cholesterol and Glycemic Index, they are good for human health. Despite the vital role played by pulse crops in the sustainability of food systems and human nutrition, research on pulse crops has remained constrained because of low levels of funding. A major initiative planned as part

Box 10.1: Major institutions where genetic resources of pulses are maintained

- Global Gateway to Genetic Resources (GENESYS) (https://www.genesys-pgr.org/)
- World Vegetable Center (AVRDC), Taiwan (http://www.avrdc.org)
- Australian Temperate Field Crops Collection, Australia (http://agriculture.vic.gov.au)
- Banco de Germoplasma – Departamento de Recursos Genéticos e Melhoramento; Estação Agronómica Nacional, Instituto Nacional de InvestigaçãAgrária, Portugal (https://www.genesys-pgr.org/wiews/PRT005)
- Centro de Investigación Agraria Finca La Orden – Valdesequer, Spain (https://www.genesys-pgr.org/wiews/ESP010)
- Centro Internacional de AgriculturaTropica (CIAT), Colombia (http://www.ciat.cgiar.org)
- Crop Germplasm Resources Information System, China (www.cgris.net/cgris_english.html)
- Crop Germplasm Resources Platform, Ministry of Science and Technology, China
- Institute of Crop Sciences, Chinese Academy of Agricultural Science, China (http://www.cgris.net/cgris_english.html)
- International Center for Agricultural Research in the Dry Areas (ICARDA), Syria (http://www.icarda.cgiar.org)
- International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), India (http://www.icrisat.org)
- International Institute of Tropical Agriculture (IITA), Nigeria (http://www.iita.org)
- International Livestock Research Institute (ILRI), Ethiopia (http://www.ilri.cgiar.org)
- Institut National de la Recherche Agronomique, France (https://urgi.versailles.inra.fr/siregal/siregal/grc.do)
- Junta de Extremadura. Dirección General de Ciencia y Tecnología, Spain (http://centrodeinvestigacionlaorden.es)
- Leibniz Institute of Plant Genetics and Crop Plant Research, Germany (http://www.ipk-gatersleben.de)
- N.I. Vavilov Research Institute of Plant Industry, Russia (http://www.vir.nw.ru)
- National Bureau of Plant Genetic Resources, India (http://www.nbpgr.ernet.in)
- National Plant Germplasm System, USA (http://www.ars-grin.gov/npgs/index.html)
- NIAS Genebank, Japan (https://www.gene.affrc.go.jp/databases_en.php)
- Plant Gene Resources of Canada (http://pgrc3.agr.gc.ca/index_e.html)
- Ustymivka Experimental Station of Plant Production, Ukraine (https://www.genesys-pgr.org/wiews/UKR008)

Source: Sivasankar *et al.* (2016).

of the activities to commemorate International Year of Pulses (2016) was a 10-Year Research Strategy for pulse crops (Sivasankar *et al.*, 2016). A review of the current state of pulse research, which served as a backgrounder to help develop future strategy, showed that, out of a total budget of USD 61 billion for public and private food and agricultural research, annually only about USD 175 million, or less than 0.3 percent, was directed towards the thirteen pulse crops (*ibid.*).

The 10-Year Research Strategy document lays out major priorities and investment requirements for research on pulse crops. Appendix 10.1 provides the main recommendations of the document. Recommendations in respect of the strategy for breeding and identification of suitable agronomic practices may be summarized as follows.

The productivity and profitability of pulses can be increased by exploiting their immense genetic diversity. This, however, requires adoption of efficient pulse-breeding programmes that aim to develop new improved varieties taking into consideration various biotic–abiotic stresses, the benefits of including pulses in cereal-based cropping patterns, and various uses of pulses as food, feed and fuel. Unlike for cereals, investment in breeding research programmes for pulses has remained at an abysmally low level. Better research initiatives need to be undertaken in order to develop new, improved short-duration cultivars with higher yields, better resistance to biotic–abiotic stresses, and enhanced soil fertility enabled by more efficient use of water and nutrients.

Research in pulse breeding must include objectives like increasing the nutritional content of pulses. Moreover, consumer preferences for specific characteristics of pulses, like taste, colour and size, must be taken into consideration. While there exists a huge diversity among pulse crops, efficient research initiatives could help in identifying certain genetic and agronomic similarities between different legumes which can further be readily adapted by another biologically related legume.

Improved pulse cultivars are bred by deriving desirable genes from various wild relatives of pulse species. Investments in processes like phenotyping, genotyping and genome sequencing are required in order to identify desirable traits among pulse variants. In order to better utilize the diverse germplasm collections, investments must be made in acquisition, accessibility and conservation of these genetic resources.

On-farm research initiatives like development of sustainable pulse-based cropping patterns for farmers need to be undertaken. Integration of pulses into various cropping systems helps in enhancing the fertility of soil and hence raises the overall productivity of all crops. Estimation tools must be developed that can aid in quantifying the benefits of adding pulses to cropping patterns in terms of the productivity and nutritive content of crops.

Research efforts must be directed towards optimizing various methods of pulse production like crop rotation, intercropping and introduction of newer pulse–cereal complementary cropping systems. Farmers need to be better trained in soil preparation, timely sowing and harvesting, use of disease-resistance varieties, chemical application, and other farm management practices. They need to be better informed so that they are able to estimate profits, risks, differences in yields and opportunity costs of introducing pulse crops into their cropping systems.

Appendix 10.1: Recommendations of the 10-Year Research Strategy for Pulse Crops*

A vision for research on pulse crops

This Research Strategy shines a light on areas of broad international agreement for strategic research priorities for pulse crops. It is clear that now is not the time for simply applying available tools to narrowly scoped problems. Rather, there is strong support for integrated approaches that emphasize sustainability and transformative potential of scientific investments. Key outcomes for agriculture, value chains, and consumers include:

- **Sustainable food systems in the face of global challenges**, specifically, agricultural systems that can meet growing global protein and micronutrient needs and are resilient to weather extremes and increased pest and disease burdens.
- **Sustainable natural resource management** including soil fertility, water use efficiency, microbial diversity, and reduced greenhouse gas emissions and environmental impacts in cropping systems.
- **Diversification as a source of agricultural sustainability and human well-being** including increasing overall productivity of cereal-based systems by inclusion of pulse crops for dynamic markets and climatic conditions and dietary diversity to combat health problems associated with under- and over-nutrition.
- **Economic sustainability at the farm scale** including reduced risks and improved farm income, supported by accessible and affordable agronomic management tools and input supply systems.
- **Sustainable value chains** that better utilize whole grain pulses and pulse fractions (for food, animal feed, fiber, and fuel) and offer consumers healthy and appealing pulse-based products through expanded public and private sector coordination and investment in agri-enterprise and food manufacturing.
- **Sustainability of research capacity, knowledge, and infrastructure** (especially in developing nations) including model-informed, farmer participatory research (especially women and youth) and pipelines for locally-adapted, end-user preferred varieties, technologies, and management practices.

This Research Strategy calls for a level of research investment that is in line with the scale of global challenges and opportunities faced by pulse crops. Responding to this call will deliver knowledge systems that lower barriers to efficient, equitable pulse value chains by providing:

- **Context-specific options for profitable, sustainable pulse production** that will enable pulse producers to anticipate and respond to emerging risks and changing market expectations and to meet global needs for stable sourcing of high-quality pulse crops.
- **Strong scientific basis for including pulses in national policies and dietary and medical guidelines**, which will allow pulses to be more financially competitive with other crops and better represented in food products and global diets.
- **Guidance for targeting public and private investment in pulse value chains**, which can unlock financing for essential infrastructure and commercial ventures.

Investing in global and regional priorities

The need for research investments that are focused on end-user needs is widely recognized. Consistent and significantly expanded investment in pulse research should focus on multiple scales.

Global and cross-regional scale

To assess status, fill gaps, and increase coordination of research functions that serve many or all pulse-growing regions (i.e. fundamental research capabilities, tools, and technologies), global platforms should emphasize:

- Assessment of available genetic resources and analysis of gaps (e.g. wild relatives, structured populations, mutant pools, and other sources of novel alleles that confer resistance to emerging abiotic and biotic stresses);
- Data-driven determination of where greater integration of pulses into cropping systems is appropriate and remunerative (e.g. diversification; reduced dependence on inputs);
- Linking different disciplines and establishing platforms for collaboration among pulse scientists and researchers working in other crop types and ecosystem services.
- Providing context for research networks that provide training and ensure quality control; and
- Taking the lead in identifying and developing research partnerships with the private sector.

* Extract from Sivasankar *et al.* (2016), pp. 43–47.

Research priorities	Global and regional functions
Germplasm resources	Global. Acquisition, maintenance, and availability of germplasm and mutant collections.
	Global. Evaluation (genotyping; phenotyping) to understand potential sources of desired traits (e.g. stress resistance; nutrient bioavailability).
	Global/regional. In situ conservation of genetic variation among wild relatives.
Genetics and genomic	Global. Tool and technology development (e.g. adapting work on other plants/biota to pulse species).
	Global. Development and maintenance of publicly available databases (i.e. genome sequences; diversity panels; phenotyping; markers).
Modeling and analysis	Global. Adaptation of existing modeling tools to pulse species including model intercomparison.
	Regional. Use of crop simulation models to better integrate geographic variability and risks into priority-setting for breeding, agronomic, and policy interventions.
	Regional. Baseline data collection and *ex ante* or *ex post* impact assessment of agriculture and value chain interventions (e.g. yield gaps, farmers' risk perceptions; desired pulse traits; market expectations; potential for nutrition and health; supply chain needs) with emphasis on women (e.g. income, household nutrition) and youth (e.g. agri-enterprise)
Crop improvement (including climate resilience)	Regional. Breeding regionally-adapted varieties that are optimized for growing conditions and objectives including yield, multiple stress resistance, water / nutrient use efficiency, suitability within farming systems (e.g. plant architecture amenable to mechanization; animal feed) and value chains (e.g. market requirements; processing suitability; uses of pulse fractions), nutrition challenges (e.g. high-iron cultivars to address anemia), and valorizing under-utilized pulse species.
Innovation pipelines	Regional. Establish or improve farmer participatory research across production pipelines and value chains (e.g. farmer levy supported projects; international development funded studies; company funded work in key sourcing regions; gender- sensitive research modes).
	Regional. Establish or improve production pipelines to deliver improved pulse varieties (i.e. pulse seed multiplication, distribution, and quality assurance systems) together with location-specific agronomic packages.
Integrated cropping systems for sustainable production	Regional. Maximize integrated management of crops, weeds, pests, and diseases including innovation in mechanization (e.g. multi-crop systems; sowing, harvesting, threshing equipment) and post-harvest technologies (e.g. hermetic bags).
	Regional. Exploit the potential of pulse-cereal systems (e.g. diversification of cropping systems and diets to meet regional targets for food /nutritional security, soil health and environmental integrity, climate change mitigation and adaptation)
Producer support programs for inclusive growth	Regional. Establish or improve producer support programs including rural advisory services and ICT platforms (e.g. pest and disease early warning; weather and market information).
Value chains and poverty reduction	Regional. Maximize value addition through quality enhancement (e.g. targeted to poverty reduction specific end uses), reduced loss (pre- and post-harvest), aggregation (e.g. storage, transport), processing (e.g. cleaning, de-hulling, milling) facilities, and market development (e.g. manufactured products; novel uses).

Research priorities	Global and regional functions
	Regional. Develop commercially viable uses and cost-effective processes for novel food (e.g. protein concentrate) and biomedical applications.
	Regional. Establish or improve sustainability reporting and food safety systems.
Sustainable consumption for nutrition and health	Global. Solidify the evidence base for contribution of pulses to malnutrition and non-communicable diseases.
	Global. Improve understanding and capacity for enhancing micronutrient bioavailability including biofortification.
	Regional. Evaluate the potential for nutritional and diet transitions (e.g. diversification, plant-based protein) and 'whole of diet' approaches.
Quantification	Regional. Quantify the impacts of pulses in cropping systems on nitrogen, water, soil biology, greenhouse gas emissions, and socio-economic dimensions (e.g. income; gender; food and nutritional security; health) to support farm-level management and accounting tools (e.g. nitrogen; multi-functionality)
	Regional. Evaluate the contribution of pulses to national targets (e.g. health and nutrition; incomes; climate adaptation and mitigation) that can feed into and policy guidelines (e.g. subsidies; minimum support prices; agriculture / rural development).
Scientific capacity and partnerships for development	Global. Replenish ranks of retiring pulse scientists through training and core funding of academic positions mandated with consistent effort toward critical challenges (e.g. focused evaluation of genetic traits).
	Global. Establish or improve cross-regional, multi-disciplinary 'challenge-focused' exchange platforms (e.g. sources of potential pest / disease resistance; water use efficiency) and food technology exchange platforms (e.g. methods for full commercial viability of pulse fractions).
	Global. Bring pulse-specific concerns into broader scientific platforms (e.g. intellectual property; spatial data; dietary studies; scientific capacity in developing countries).

Regional and local scale

Agricultural systems and public health challenges vary dramatically across major regions of the world. Hence, while the same basic research functions are needed in all regions, the structure and focus of research activities will vary based on regional characteristics. To establish or enhance delivery of 'universal' research functions in regionally-adapted ways (i.e. focused on region-specific challenges and opportunities in production, nutrition, health, markets, and supply chains), integrated research programs will need to address a wide range of issues such as:

- Breeding and use of relevant pulse species and cultivars for specific growing conditions and uses;
- Location-specific agronomic practices and production technologies;
- New types of sustainable, diversified cropping systems optimized for specific regions;
- Socio-economic dimensions of production and consumption;
- Value chain / market conditions and consumer preferences;
- Locally and regionally relevant policies and enabling environments; and
- National level capacity to undertake research (e.g. through intra- and cross-regional partnerships).

The table below summarizes major research functions that require investment at global (or cross- regional) and regional (or local) scales. Many of these recommendations are specific to pulse crops. Others that are relevant to all crops will maximize and accelerate scientific advances for pulse crops.

Investing in the pulse research community

The mandate for the International Year of Pulses is to encourage connections throughout the food chain that would better utilize pulse-based proteins, to further global production of pulses, to increase the efficiency of cropping systems, and to address trade challenges. The pulse research community plays several critical roles in meeting this mandate. A strong, multi-scale global pulse research community that integrates work across all countries and regions, is capable of meeting local to global needs, and is well- linked to the broader agricultural science community is central to the vision described here. This requires investment in the regional and global pool of scientists capable of addressing critical needs in pulse breeding and genetics, agronomy, nutrition and health, socio-economic dimensions, and spatial analysis. Collaboration anchored in global and regional networks of scientists, government partners, and industry players is necessary for improved productivity and sustainability of pulses. Dedicated support is needed for pulse scientists to establish and sustain collaboration with food scientists, cereal crop researchers, medical scientists, the food industry, and policy communities.

Call to action

These recommendations are directed at public and private sector stakeholders in government, agriculture, health, the food industry, consumer groups, foundations, funding agencies, and research institutions.

- **Industry groups**, such as the Global Pulse Confederation, are essential research partners in developing value addition pathways for pulse-based products by engaging local agri-enterprises, regional partners, and major food companies and promoting innovation and transparency in pulse value chains. Industry groups can serve as conduits for scientific knowledge to their members.
- **National governments** can utilize research findings to target public investments, policies, and enabling environments designed to promote pulse production and consumption as part of climate- smart economic development (e.g. for export as well as in-country pre-processing and value addition for local markets) and public health (e.g. dietary diversification to combat malnutrition). National programs and regional intergovernmental initiatives are critical to guiding and funding priority research and establishing or modernizing pulse supply chain infrastructure and information systems (e.g. spatial planning; rural advisory services; agricultural statistics).
- **Research institutions** are the engines of knowledge and innovation that can serve as nodes for regional collaboration among public and private sector partners and lead development of appropriate pulse varieties, technologies, and practices that are resilience to climate and market conditions and reduce labor demand and risks. By quantifying the benefits of pulses for different social groups, researchers can support their integration into public and private initiatives targeting local and global sustainability challenges.
- The mandates of **global donors** and **international agencies** would benefit from greater integration of pulse crops into their programs. Agricultural development, humanitarian, and finance organizations in public and philanthropic sectors can use research findings to capitalize on the benefits of pulses for agricultural sustainability and human well-being.
- **Producer associations** are pivotal to designing and conducting research that is responsive to real- world agricultural constraints (e.g. biotic and abiotic stresses; market dynamics) and possibilities (e.g. increased yield; efficient resource use). When these groups can co-invest with government, they are well-positioned to serve as effective knowledge hubs for their members.
- **All stakeholders** can work to ensure that pulses are included in major policies and sustainability finance mechanisms (e.g. Green Climate Fund).

Increased production and consumption of pulses is essential if global agriculture and food systems are to stay within planetary boundaries. In the coming decade, collective action toward a shared vision for investing in pulse crops research can deliver impactful, efficient scientific progress that unlocks the potential of pulses for agricultural sustainability and human well-being.

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Pulses are highly nutritious and a valuable component of healthy food systems. Despite this, per capita consumption of pulses in most parts of the world has remained low and stagnant. Further, cultivation of pulses plays a crucial role in sustainable intensification of agriculture. Through nitrogen fixation in the soil, pulses displace the use of fossil fuel-based nitrogen fertilizers.

In view of the importance of pulses in healthy diets and sustainable food systems, 2016 was celebrated as International Year of Pulses. *The Global Economy of Pulses*, produced by the Trade and Markets Division of FAO with partial support from the IYP Multilateral Trust Fund, is a key research output of the year.

The Global Economy of Pulses shows that considerable growth has taken place in pulse production over the last fifteen years in several countries of the world, including in South Asia and sub-Saharan Africa, as well as Canada, Australia and Myanmar. This growth was a result of concerted public action towards developing improved varieties and identifying suitable agronomic varieties, and due to initiatives to take improved technologies which made cultivation of pulses economically attractive to farmers in diverse agro-climatic regions.

The Global Economy of Pulses argues that there is a pressing need to close the large gap between potential and actual yields, particularly on smallholder farms in South Asia and sub-Saharan Africa, by increased adoption of improved varieties and modern agronomic practices in all developing countries. This in turn requires a major thrust in agricultural research and extension, improving credit availability, and public investment directed towards pulse production.

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